Department of Energy
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DEC - 7 [illegible]

Michael H. Schlender
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SUBJECT: DOE APPROVAL OF THE HAZARD CLASSIFICATION AND AUDITABLE SAFETY ANALYSIS (BGRR-002): BROOKHAVEN GRAPHITE RESEARCH REACTOR DECOMMISSIONING PROJECT (BGRR-DP)

Reference: Safety Evaluation Report (SER), Brookhaven Graphite Research Reactor Decommissioning Project dated October 15, 1999

This letter transmits the approved subject document for project execution. The basis for this approval is contained in the referenced SER. The SER contains the technical evaluation for compliance with applicable requirements contained in DOE Orders and Standards. The approved ASA and SER constitute the Safety Authorization Agreement between DOE and Brookhaven Science Associates. These document will be placed under configuration management. All commitments and controls established in the ASA and SER will be strictly enforced.

The BGRR-DP is classified as "RADIOLOGICAL" on an interim basis, not to exceed one year from the date of approval of the ASA, at which time the ASA will be updated based on additional radiological characterization data. The work scope approved by this ASA is limited to surveillance, routine maintenance and radiological/hazardous characterization.

Each phase of the decommissioning project will be preceded by additional characterization and hazards analysis after the work scope has been defined through an Engineering Evaluation/Cost Analysis and screened using an approved Unresolved Safety Issue Determination (USID) process. Hazards analysis or safety evaluations performed as a result of the USID process will be reviewed by the BGRR-DP Project Office and the DOE Brookhaven Group, and approved by the undersigned. Approved USIDs will be placed under configuration management and become an appendix to the Safety Authorization Agreement.

Should you have additional questions of comments, you may contact Mr. James D. Goodenough on ext. 2423.

Sincerely,

George J. Malosh
Brookhaven Group Manager

Enclosures:
As stated

cc: M. Stahr, EM-441, GTN, w/o encls.
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BGRR-002
Rev. 2

Hazard Classification and Auditable Safety Analysis for Brookhaven Graphite Research Reactor (BGRR) Decommissioning Project

September 8, 1999

BROOKHAVEN NATIONAL LABORATORY
BROOKHAVEN SCIENCE ASSOCIATES
Under Contract No. DE-AC02-98CH01886 with the
UNITED STATES DEPARTMENT OF ENERGY

APPROVAL PAGE

Title of Document: **Hazard Classification and Auditable Safety Analysis for the Brookhaven Graphite Research Reactor (BGRR) Decommissioning Project**

Author: Steven H. Moss

Approval:

Steven H Moss — 9/7/99
S. Moss, Licensing Support Engineer — Date

Clyde T. Newson — 9/7/99
C. Newson, Project Engineer — Date

Stephen K. Pulsford — 9/8/99
S. Pulsford, Project Manager — Date

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FOREWORD

Based upon the Memorandum of Agreement signed between the Department of Energy's Office of Science (DOE-SC) and the Office of Environmental Management (DOE-EM) on the management of work associated with the surplus Brookhaven Graphite Research Reactor (BGRR), ownership was transferred on February 17, 1999 [1]. With that transfer, the direction of the Project was modified, necessitating a new plan of action.

This document was revised to reflect these changes in the BGRR Decommissioning Project and to address the comments raised by the current DOE Office holding overall responsibility for its management.

Among the major changes incorporated into this version are the following:

- Reconfiguration of the old document from the format of a Basis of Interim Operation (BIO) into an Auditable Safety Analysis (ASA).
- Reduction of the scope of characterization, from full site characterization by survey unit, to characterization for waste management and occupational/radiological safety on a work package basis.
- Introduction of a formal safety evaluation for the process of Unreviewed Safety Issue Determination to examine the scope of work not covered by this document.
- Commitment to completing the stabilization and isolation of Building 702, Reactor Pile, from all other buildings/work to be covered under this document.

EXECUTIVE SUMMARY

The objective of this Hazard Classification and Auditable Safety Analysis (ASA) for the Brookhaven Graphite Research Reactor (BGRR) Decommissioning Project is to identify the facilities' conditions, hazards, authorized activities, safety-management programs, and appropriate safety controls for the BGRR Decommissioning Project. In keeping with the graded approach, this ASA uses existing documentation and analyses as far as possible, while duplicating only those portions required for a sufficient understanding of the facility and project without needing to directly consult the referenced documents. In conducting the hazards analysis to develop this ASA, the focus was limited to identifying and evaluating bounding scenarios. This limited scope is deemed appropriate based on the use of the graded task-based hazards analysis for the BGRR Decommissioning Project [2]. This process is discussed in the Hazard Analysis section of this document.

The BGRR-ASA document summarizes the known inventories of radioactive- and hazardous-materials present and at risk within the BGRR, and considers the following operations that will be undertaken: implementation of the Project Management Plan; regular, ongoing stabilization work, surveys/monitoring for the radiological protection of personnel working in or visiting Buildings 701, 702, 704, 708, 709, 709A, and the associated yard area; removal of contaminated water from various BGRR sumps already analyzed by the Department of Energy (DOE) in their reviews of submitted safety evaluations; continuing prevention and elimination of the intrusion of storm water into the contaminated portions of the BGRR facility; and related non-specific activities, to immediately protect the environment from unmonitored releases (actual or potential) originating from within the BGRR.

The BGRR Deactivation Basis for Interim Operations (BIO) [3], which was distributed for comment to Brookhaven National Laboratory (BNL), the Department of Energy's Brookhaven Group (DOE/BHG) and Chicago Operations Office (DOE/CH) on April 15, 1998 by the BGRR Project Manager, classified the facility as Nuclear Hazard Category 2 (which has no upper limit on inventory and so cannot be upgraded to Category 1 based on inventory). The Preliminary Hazard Analysis (PHA) in that document was extremely conservative in the following ways:

1. It included the inventory in Building 701's Nuclear Material Storage Vault that could have been excluded because the material is packaged in Department of Transportation's (DOT) Type B containers, and the vault is segmented,
2. It placed the entire radionuclide inventory at risk for all postulated accidents without considering mitigation represented by the robust structural integrity of building and shielding material,
3. It did not consider the form and distribution of radiological material, and

4. It did not address the limited energies available for initiating events based on the tasks to be covered under the BIO (which evolved into the current ASA).

Subsequent reviews and resolution of comments, ultimately resulting in this ASA document, re-evaluated the best conservative estimate of the following parameters:

1. The radiological material at risk of release by postulated accidents,
2. The conservatism in DOE-STD-1027-92 [4] Category 3 Threshold values for the type of facility and work planned,
3. The form, distribution, and dispersibility of the radioactive materials, and
4. The energy sources available to initiate events, as determined by the accident- and hazards-analysis, demonstrating that there were no credible release mechanisms for operations covered by this ASA.

Based on this reevaluation (in Section 2.3, Inventory of Hazardous Substances and Section 3.3, Hazards Analysis), the BGRR Decommissioning Project is designated **RADIOLOGICAL FACILITY**, as per DOE-EM-STD-5502-94 [5].

From the scenarios and hazards identified, there are no Technical Safety Requirement (TSR) systems associated with the BGRR facility during operations scheduled under this ASA; however, several administrative work controls are required. These controls will reduce the risk associated with the anticipated work, during the implementation of the Project Management Plan [6]. Operations within the scope of this ASA, performed in accordance with appropriate work control and limits, do not pose an unacceptable level of risk to the workers, on-site personnel, the public, or the environment.

Proposed activities not specifically addressed under this ASA will be reviewed against BGRR-SOP-0902, *Safety Evaluations for Unreviewed Safety Issue Determinations* [7], to determine if there are any Unreviewed Safety Issues (USIs). If so, USIs (with their associated safety evaluations) will be submitted to the DOE Manager for the BGRR Decommissioning Project for review and approval before undertaking the proposed activity in accordance with DOE Order 430.1A, *Life Cycle Asset Management* [8].

ACRONYMS AND ABBREVIATIONS

AEC	Atomic Energy Commission
ALARA	As Low As Reasonably Achievable
ASA	Auditable Safety Analysis
BGRR	Brookhaven Graphite Research Reactor
BIO	Basis for Interim Operation
BNL	Brookhaven National Laboratory
BOP	Balance of Plant
CAM	Continuous Air Monitor(ing)
CANDU	Canadian Deuterium Uranium (Reactor)
CERCLA	Comprehensive Environmental Response, Compensation, and Liabilities Act
CFR	Code of Federal Regulations
CX	Categorical Exclusion
D&D	Decontamination and Decommissioning
DOE	Department of Energy
DOE-CH	Department of Energy, Chicago Operations Office
DOE-EM	Department of Energy, Environmental Management Office
DOE-SC	Department of Energy, Office of Science
DOT	Department of Transportation
EPA	Environmental Protection Agency
ES&H	Environment, Safety, and Health
EU	Enriched Uranium
FEMA	Federal Emergency Management Agency
HEPA	High Efficiency Particulate Air
HFBR	High Flux Beam Reactor
HP	Health Physics
HVAC	Heating, Ventilation and Air Conditioning
ISMS	Integrated Safety Management System
LLW	Low-Level Waste
MAR	Material at Risk
MOA	Memorandum of Agreement
MWt	Megawatts Thermal

NEPA	National Environmental Policy Act
NFPA	National Fire Protection Association
NU	Natural Uranium
OSHA	Occupational Safety and Health Administration
PCB	Polychlorinated Biphenyl
PHA	Preliminary Hazard Analysis
PHC	Preliminary Hazard Classification
PNPS	Pile Negative Pressure System
QAPP	Quality Assurance Project Plan
RQ	Reportable Quantities
RWP	Radiation Work Permit
SAR	Safety Analysis Report
SE	Safety Evaluations
SNM	Special Nuclear Material
TLD	Thermoluminescent Dosimeter
TQ	Threshold Quantities
TSR	Technical Safety Requirement
USI(D)	Unreviewed Safety Issue (determination)
USQ(D)	Unreviewed Safety Question (determination)
WIPP	Waste Isolation Pilot Project

1.0 INTRODUCTION

1.1 Purpose and Content

The objective of this Hazard Classification and Auditable Safety Analysis (ASA) for the Brookhaven Graphite Research Reactor (BGRR) is to identify the facility's conditions, hazards, authorized project activities, safety management programs, and appropriate safety controls for the BGRR Decommissioning Project. In keeping with the graded approach, this ASA uses existing documentation and analyses as far as possible, while duplicating only those portions required for a sufficient understanding of the facility and project without needing to directly consult the referenced documents. In performing the hazards analysis to develop this ASA, the focus was limited to identifying and evaluating bounding scenarios. This limited scope is deemed appropriate based on the use of the graded task-based hazards-analysis for the BGRR Decommissioning Project Management Plan. This process is discussed in the Hazard Analysis section of this document.

The goal of this document is to determine the appropriate hazard categorization and define the authorization basis for the BGRR. This was done by examining and analyzing the associated hazards and setting up of physical and management systems controls.

This report includes the following items:

- a description of the operations to be performed during the BGRR Decommissioning Project,
- an assessment of the total inventory of radioactive- and hazardous- materials associated with the Project.
- an identification of the hazards associated with the tasks of the Project,
- an identification of internally and externally initiated accident scenarios with the potential to have significant local consequences during the Project,
- a bounding evaluation of the consequences of the potentially significant accident scenarios,
- a hazard classification based on evaluating the bounding consequences and material-at-risk (MAR),
- a listing of safety functions and controls, including commitments.
- a consideration of controls to protect employee safety, health, and environmental and radiological issues.
- a description of the methodology to be used to evaluate proposed work that may not be described and in this ASA.

Section 1.2 describes the overall approach used in hazard classification, and Section 1.3 summarizes the findings and commitments to administrative controls.

The following sections are also contained in this document:

Section 2.0 lists the hazardous-material inventories, describes the work to be undertaken during the BGRR Decommissioning Project, and discusses related information, such as demographics and the site features.

Section 3.0 identifies the hazards and the risks associated with the BGRR Decommissioning Project and contains the hazard classification analysis.

Section 4.0 summarizes the controls and commitments applicable to the Project.

1.2 Overall Approach

Potential initiating events are analyzed by taking into account the form, location, and dispersibility of the radioactive material and its interaction with available energy sources, as allowed by the following: DOE-EM-STD-5502-94, *Hazard Baseline Documentation;* DOE-STD-1027-92, Change 1, *Hazard Categorization and Accident Analysis Techniques for Compliance with DOE Orders 5480.23, Nuclear Safety Analysis Reports*; DOE-HDBK-3010-94, *Airborne Release Fractions/Rates and Respirable Fractions for Nonreactor Nuclear Facilities* [9]; and BHI-00837, Bechtel Hanford, Inc., *Final Hazard Classification and Auditable Safety Analysis for the 105-C Reactor Interim Safe Storage Project* [10].

The following is the approach taken for classifying the hazard for the BGRR Decommissioning Project.

- Not all of the total radioactive inventory is at risk.
- Not all of the radioactive inventory at risk may contribute to the exposure of individuals.
- The collective MAR inventory is below the Category 3 Facility Threshold of DOE-STD-1027-92, Change 1.

By identifying the amount of the radioactive material inventory that credibly contributes to the exposure of individuals, a hazard category can be assigned that reflects the true hazard represented by the BGRR Decommissioning Project.

The specific steps involved in the hazard analysis and initial hazard-classification are summarized below. No active features that could prevent or mitigate the exposure of individuals are considered in the evaluations.

Step 1 The credible hazards associated with the operations to be performed during the BGRR Decommissioning Project are identified and discussed. Based on this analysis, a set of accident scenarios with potentially significant consequences is identified.

Step 2 The inventory is estimated for each scenario identified using data from radioactive material inventories generated in various analyses conducted and referenced in this report, taking into account their physical location.

Step 3 The physical and chemical form of the radioactive material at risk (e.g., activation, fixed contamination, smearable contamination) for the operations covered by the ASA is integrated with the energy sources introduced by the scenario; from this, the thresholds for Hazard Category 3 are compared to allow for the direct application of Table A.1, Thresholds for Radionuclides in Appendix 1 of DOE-STD-1027-92, Change 1.

Step 4 Necessary functions or controls (including administrative control commitments) are specified to ensure that the risks associated with the operations during the BGRR Decommissioning Project and the assumptions and bases of hazard classification remain valid, so that employees' safety and health are not endangered.

1.3 Hazard-Classification Summary

The BGRR Deactivation Basis for Interim Operations (BIO), distributed for comment to BNL, DOE/BHG, and DOE/CH on April 15, 1998 by the BGRR Project Manager, classified the facility as Nuclear Hazard Category 2 (which has no upper limit on inventory and so cannot be upgraded to Category 1 based on inventory). The Preliminary Hazard Analysis (PHA) contained within that document was extremely conservative in the following ways:

1. It included the inventory in Building 701's Nuclear Material Storage Vault that could have been excluded because the material is packaged in the Department of Transportation's (DOT) Type B containers, and the vault is segmented,
2. It placed the entire radionuclide inventory at risk for all postulated accidents without considering mitigation represented by the robust structural integrity of building and shielding material,
3. It did not consider the form and distribution of radiological material, and
4. It did not address the limited energies available for initiating events based on the tasks to be covered under the BIO (which evolved into the current ASA).

Subsequent reviews and resolution of comments, ultimately resulting in this ASA document, re-evaluated the best conservative estimate of the following parameters:

1. the radiological material MAR of release by postulated accidents,
2. the extreme conservatism in the DOE-STD-1027-92 Category 3 Threshold values for the type of facility and work planned,
3. the form, distribution, and dispersibility of the radioactive materials, and
4. the energy sources available to initiate events as determined by the accident- and hazards-analysis demonstrating that there were no credible release mechanisms for activities covered by this ASA.

Based on this re-evaluation (in Section 2.3, Inventory of Hazardous Substances and Section 3.3, Hazards Analysis) the BGRR Decommissioning Project is designated **RADIOLOGICAL** as per DOE-EM-STD-5502-94.

BNL's radiological and industrial safety procedures are judged adequate to control the work on the BGRR Decommissioning Project. Appendix A identifies some of these procedures. Five additional administrative controls[1] are established:

Administrative Control #1: Welding/torch cutting on or within 18 inches of the biological shield is prohibited without an approved safety evaluation to demonstrate that the work is safe (margin of safety to prevent igniting graphite or graphite dust).

Administrative Control #2: Electrical penetrations through the biological shield will be isolated from power sources before any other work begins on or near Building 702 Reactor Pile, along with other enhanced means of stabilization to minimize all leakage of air into the bioshield.

Administrative Control #3: The safety programs identified in Section 4.0, Controls and Commitments, are required for authorization of operations within the BGRR complex. This control requires that the programs are instituted by the Project. Individual and specific deficiencies within a program do not constitute a noncompliance with this control; however, multiple deficiencies within a program may indicate a failed program and should be corrected promptly to ensure compliance.

Administrative Control #4: Since the current classification of the facility is "Radiological," introducing additional radiological material could change this categorization. Therefore, an administrative control was instituted, prohibiting the taking of additional radioactive material

[1]Administrative controls are those provisions relating to organization and management, record keeping, job reviews, and work practices necessary to ensure safety at the facility. The administrative controls necessary for the BGRR-ASA are those factors already taken credit for in the risk assessment.

into the BGRR facility, excluding the temporary introduction of sealed check sources to calibrate instruments, or sealed sources to image inaccessible areas.

Administrative Control #5: Since the facility was determined to be "Routine Risk," partly due to the limited combustible material loading and no significant inventory of nonradiological hazardous material, those conditions must be maintained as an administrative control.

DOE-STD-3009-94, *Preparation Guide for U.S. Department of Energy Nonreactor Nuclear Facility Safety Analysis Reports* [11], states "Safety Limits are reserved for a small set of extremely significant features that prevent potentially major off-site impact." The Safety Analysis of the BGRR ASA shows that only localized consequences can be expected as long as the radiological inventory at risk remains below the threshold for Nuclear Hazard Category 3 (adjusted as necessary and appropriate) and the other mitigating factors taken credit for are in place. Also, no credible accident consequence exceeds the classification of "Routine Risk" as defined in BNL's Environment, Safety, and Health (ES&H) Manual, Standard 1.3.3, "Safety Analysis Reports/Safety Assessment Documents" [12]. Therefore, no safety limits are required for the BGRR facility as part of this BGRR-ASA.

1.4 Scope of Work

The following are the operations planned at the BGRR Complex that are covered by this document:

- routine monitoring of the physical plant for radiological- and nonradiological-hazards,
- characterization sampling for ES&H concerns, waste management, and USI-analyses for various decommissioning tasks,
- undertaking routine facility maintenance and upkeep (including stabilization tasks, e.g., enhancing the isolation of Building 702, as necessary),
- removing any contaminated water from various BGRR sumps,
- preventing and eliminating the intrusion of storm water into contaminated portions of the BGRR facility, and
- undertaking unspecified work to immediately protect the environment from unmonitored releases (actual or potential) originating from within the BGRR Complex.

The following activities performed at the BGRR Complex are not covered by this document and require evaluation for Unreviewed Safety Issue (USI) Determination:

- decommissioning tasks, such as removing fans from Building 704 and installed equipment from Building 701,

- CERCLA Non-Time Critical Removal Actions, such as above-grade duct work and removals from Building 708, below-grade duct removal, Canal House and Water Treatment Building removal, and
- permanent or long-term disposition tasks related to the Reactor Pile and Bioshield (Building 702).

Table 1.1 provides a matrix of activities and shows whether they are intended to be covered by the BGRR ASA.

Table 1.1

ASA APPLICABILITY TABLE

Activities	BGRR ASA covers planned work	USI needed to cover planned work
Surveillance and Maintenance	Yes[1]	No
Characterization sampling for ES&H concerns, waste management and USI analysis of various decommissioning tasks	Yes	No
Work planning and facility "hands-off" inspections	Yes	No
Early National Environmental Policy Act-Categorical Exclusion (NEPA-CX) maintenance tasks, such as removing museum material and housekeeping items	Yes[2]	No
NEPA-CX decommissioning tasks, such as removing fans from Building 704 and equipment from Building 701	No	Yes
CERCLA removal actions, such as the above-grade duct and 708 removal, below-grade duct removal, Canal House, and Water Treatment Building removals	No	Yes
Waste packaging and disposal for any of the above actions	Yes[3]	Yes[3]

Notes:

1. Routine Surveillance and Maintenance are covered by ASA; however, if large unanticipated maintenance tasks are needed, a USI would evaluate them.
2. Removal of BNL Science Museum materials already authorized by DOE, independent of the final approval of the ASA.
3. Waste will be dealt with along with the Surveillance and Maintenance, NEPA, or CERCLA work that generates the particular waste stream.

1.5 Unreviewed Safety Issue (USI) Process

The USI Determination process is based on the comparable Unreviewed Safety Question Determination (USQD) applicable to nuclear facilities (DOE Order 5480.21, *Unreviewed Safety Questions* issued, 12/24/91). The BGRR Decommissioning Project's procedure on USI and associated Safety Evaluations (SE) was modeled after the approved USQD/SE procedure for the BNL Waste Management Facility (HWM-ADM-910, *Safety Evaluations for Unreviewed Safety Question Determinations*, Rev. 0, dated 2/7/97), a nuclear non-reactor Hazard Category 3 facility, using a graded approach.

The process involves analyzing the proposed activity, answering a series of questions with "yes" or "no." When an answer is "yes," then a USI exists and DOE must review and approve the Unreviewed Safety Issue Determination/Safety Evaluation (USID/SE) before work can begin.

The USI process will be supported by detailed characterizations, detailed engineering and work packages, radiological work procedures, and a Project-Specific Health and Safety Plan prepared in accordance with 29 CFR 1910.120, *Hazardous Waste Operations and Emergency Response (HAZWOPER)*, dated 9/25/98, and 29 CFR 1926.65, *Safety and Health Regulations for Construction*, updated 9/11/98.

The questions concern the operation's anticipated impact on the following:

- any safety functions or established failure modes of equipment within the facility,
- creation of new failure modes,
- potential increase in the probability of occurrence of an accident previously evaluated in the authorization basis documentation (ASA and approved USID/SEs),
- potential occurrence of a malfunction of equipment, systems and components that are important to safety,
- potential occurrence of an accident of a different type than those previously evaluated in the ASA,
- potential equipment, system and component malfunction of a different type than those previously evaluated in the ASA,
- potential for change in the margin of safety as defined in the ASA, and
- change of the facility's configuration as described in the ASA.

Whether the answer to the question asked is "yes" or "no," sufficient supporting data must be provided for an independent review. For questions answered "yes," analytical data should be provided in the responding text that is at least comparable in depth to that in the ASA and of sufficient breadth to warrant DOE's approval with a confident expectation of no significant impact.

2.0 BACKGROUND

2.1 Facility/Systems Description

2.1.1 Operational Overview

The BGRR was a graphite-moderated and -reflected, thermal neutron, air-cooled research reactor facility. The original fuel loading was natural uranium (NU) and its core reached criticality on August 22, 1950. The final loading was changed to enriched uranium (EU) fuel elements in April 1958. The reactor was finally shut down in1969. The nominal power level of the reactor was 28 megawatts thermal (MWt) during the NU fuel loading, and 20 MWt during the EU fuel loading [13].

The graphite moderator was regularly annealed during operation, and was again annealed in 1970 to remove any residual stored energy; while all the remaining fuel was shipped to the DOE's Savannah River site in 1972. The BGRR complex was described as being in a safe shutdown condition by the U.S. Atomic Energy Commission (AEC) and became an "orphaned" facility within the DOE complex. From 1977 until 1997, portions of the facility were used as BNL's Science Museum. (See Figure 2.1, BGRR Site Layout Diagram [14].)

2.1.2 History of Operation

The fuel elements were charged and discharged from the south face of the graphite pile through openings in the biological shield's wall which match the fuel channels in the graphite pile. The spent fuel was lowered into a chute or a cart, which then was emptied into the chute extending from the floor of the south plenum to the bottom of the deep pit. The deep pit was part of the water-filled canal that served to shield, store, and prepare fuel elements and activated sources for shipment. The canal is 64 feet long and 8.5 feet deep, except for the 20-foot deep-pit area near the reactor.

The other five faces of the reactor are penetrated by an assortment of experimental openings. The east- and west-faces also have eight penetrations each for control rods. Following permanent shutdown, the control rods were disconnected from the drives and inserted into the graphite pile. The biological-shield penetrations for the control rods were covered with metal plates and tack-welded into place. The experimental openings were closed or plugged.

Radioactive equipment was removed from the experimental area and the underwater canal. The canal water was pumped down to the Building 801 Radioactive Waste Processing Facility. It was cleaned with soap and water (which pumped to Building 801 as well) and covered with concrete slabs for shielding.

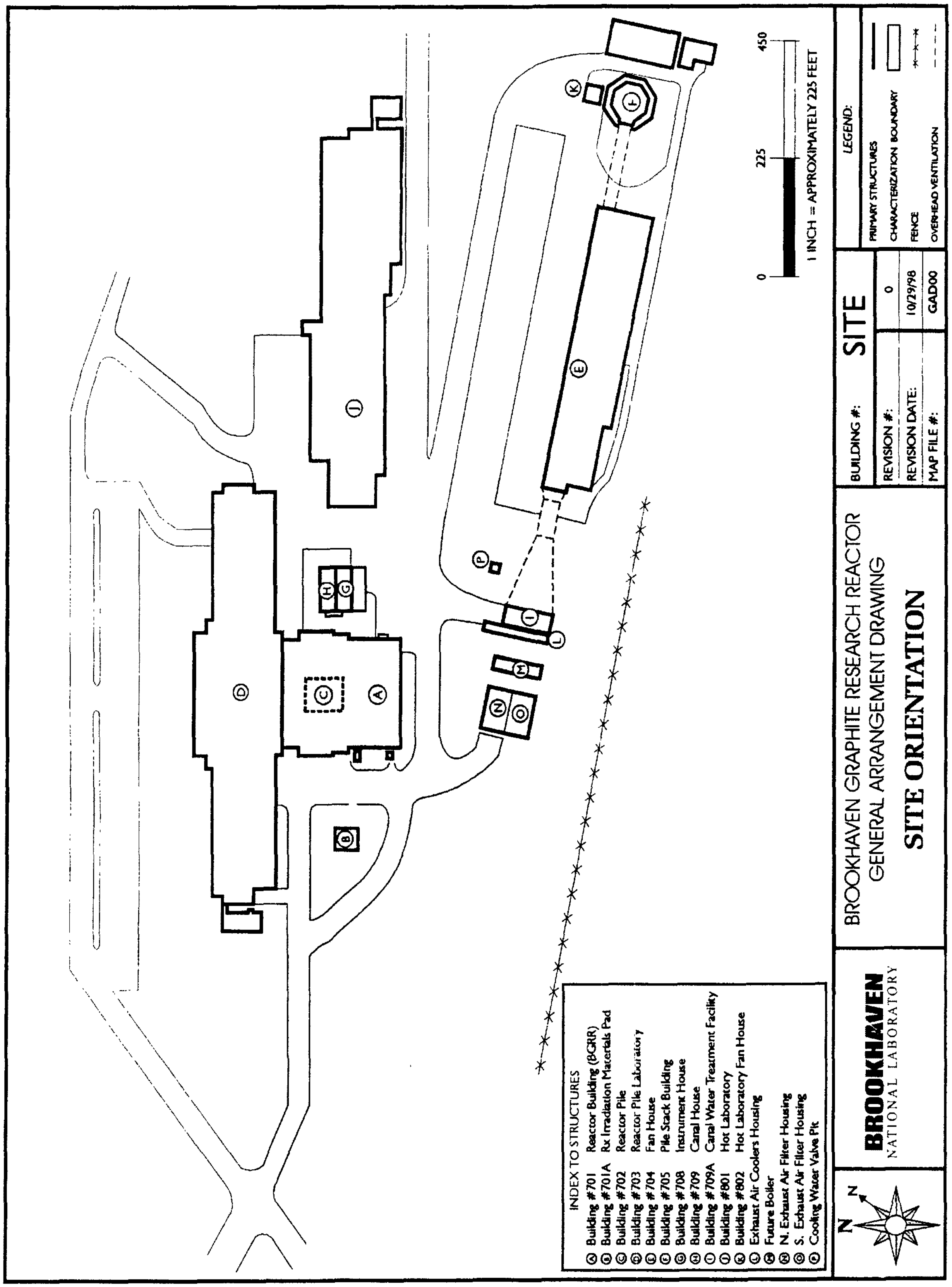

Figure 2.1. BGRR Site Layout Diagram

Appendix B provides detailed information on the construction and operations history of various components and structures within the BGRR Complex.

2.1.3 Current Status of Facility

Since 1973, very little has been done to the reactor itself. Its present status is as follows [15]:

- The graphite was annealed.
- The fuel was removed.
- The shot is in the shot-wells.
- The sixteen control rods were cut from their drive mechanisms and fully inserted into the graphite. Also, the openings for the control rods were covered with tack-welded steel plates.
- The experimental holes were closed or plugged.
- The removable core-experimental facility remains inside the graphite Pile and its opening was plugged.
- The removable roof is intact.
- The animal- and instrument-tunnels' access ways were plugged.
- The exhaust-duct's isolation valves were closed.
- The east and west air-inlet ducts were closed off at their ends by plywood (15' x 4', and soon to be replaced by steel plate or otherwise fireproofed as part of the planned enhanced stabilization).
- A negative-pressure system for the Pile was installed in the east intake filter house. This system operates at all times and is monitored via LCM-14.
- The thermocouples (approximately 100-200) were cut from their indicating devices and left inside the biological shield. These devices are a source of cobalt-60.
- Various apparatus may remain in the graphite, plenums, exhaust duct heels, or between the beams under the Pile. This equipment includes pneumatic tubing, experimental piping associated with the Chem-Nuclear Loop, the target-conveyor equipment, the stabilizing springs for the Pile, and the chromel-alumel thermocouples used on fuel elements.
- The pneumatic tubes at the entry of Buildings 801 and 703 were physically isolated.
- All water from the deep drain sump was removed (approximately 57,000 gallons).

In accordance with BGRR-SOP-0901, “Brookhaven Graphite Research Reactor (BGRR) Monitoring and Surveillance Procedure” [16], the following monitoring and surveillance is routinely conducted at the BGRR complex at the following locations:

- Water Intrusion Level Surveillance Monitoring (typically every 2 weeks or after any heavy precipitation):

  - North Cooler Drain Sump (pneumatic-level check),
  - South Cooler Drain Sump (pneumatic-level check),
  - Secondary air cooling north exhaust outlet bustle (pneumatic-level check),
  - Secondary air cooling south exhaust outlet bustle (pneumatic-level check),
  - Deep Drain Sump (pneumatic-level check, and also recorded and monitored remotely in Building 600 by Plant Engineering personnel),
  - Walkway Sump (pneumatic-level check),
  - East Yard Sump (visual check), and
  - Instrument House Sump (visual check).

- Physical Condition Inspection/Surveillance Monitoring is conducted at the following locations (typically monthly or as needed when there are special radiological entry requirements):

  - Building 701, Reactor Building
  - Building 702, Pile
  - Building 704, Fan House
  - Building 708, Instrument House
  - Building 709, Canal House
  - Building 709A, Water Treatment House
  - Exhaust Air Installed Filter Cover
  - Exhaust Air Future Auxiliary Boiler Cover
  - Exhaust Air Cooling Coils Cover
  - Above ground Duct Berms
  - Above ground Duct Work
  - BGRR Complex Paved Area
  - Chem-Nuclear Loop Vault
  - Building 703 West Wing Sump Pit

- Routine Radiological Surveys

  The following surveys are performed *weekly*:

  - 701, 110' General Walkways
  - 701, 110' General Area (air sampling)

- 702, Pile Exhaust Air Monitoring (Continuous Air Monitoring [CAM]) (air sampling)
- 702, Pile Exhaust Pre-HEPA (air sampling)
- 702, Pile Exhaust Post-HEPA (air sampling)

The following survey is performed *monthly*:

- 701, 110' Source Vault

The following surveys are performed *quarterly:*

- 701, 110' General Walkways
- 118', 127', 133' General Walkways
- 143' General Walkways
- 701, 133' Offices
- 701, 143' Offices

The following survey is performed *biannually:*

- 701, 110' Health Physics (HP) Office Source Accountability

The following surveys are performed *annually*:

- 701, Parking Lot South and East Side
- 704, Fan House
- 708, Instrument House
- 709, Canal House
- 709, Outside Area

Following the Plant Engineering Maintenance/Testing Program, all fire-alarm panels are tested annually in accordance with NFPA recommendations. Furthermore, BNL's Site-wide Fire Alarm System - System 1000 Operations Manual, dated March 1994 [17] indicates that the main computer for the site-wide fire-alarm system polls the status of each fire-alarm panel every seven seconds, including the fire-alarm panels associated with the BGRR Complex.

2.2 Project Description

The proposed objectives for the BGRR Decommissioning Project are detailed in the BGRR Project Management Plan [6], and are summarized as follows:

- Determining the type, variability, and extent of radiological- and hazardous-material contamination to aid in assessing the appropriate health physics controls for work planning.

- Developing and implementing plans for CERCLA removal actions.
- Estimating the occupational and public health and safety impacts during the Project,
- Determining the inventory of radioactive materials to confirm the final hazard characterization and to establish mitigation methods.
- Stabilizing the BGRR wherever it is deemed necessary to protect the public and the environment against any actual or potential unmonitored radiological release.
- Classifying wastes to demonstrate that transportation and disposal criteria will be met (waste-acceptance criteria).
- Estimating the types and volumes of waste requiring disposal.
- Undertaking maintenance, as allowed for under one or more of the Laboratory's NEPA Categorical Exclusions.
- Estimating costs associated with stabilization, decontamination, and decommissioning.

The data to be generated by implementing the Project plan will have many uses. Therefore, it is important to fully understand the potential uses of these data before their generation. Those were the basis upon which the Project plan was developed. The following lists the major anticipated uses of the Project data:

- Decommissioning planning and engineering.
- Determinating the scope of the remedial work to stabilize the BGRR.
- Selecting decommissioning and dismantling techniques.
- Developing strategies for waste disposal.
- Refining decommissioning cost-estimates and schedules.
- Benchmarking the accuracy of the analysis of neutron activation.
- Updating the BGRR authorization basis and the facility's hazard category, as necessary.
- Providing data for developing radiological limits equivalent to regulatory-release criteria via pathways-analysis techniques.
- Providing input to formulate or modify procedures for health physics, safety, radioactive waste-handling, and environmental monitoring specific to any planned decommissioning programs.
- Supplying input to develop the final survey program which will document the facility's status.

The scope of the Project includes evaluations of remediation alternatives, where required, as part of planning for CERCLA removal actions.

In addition to the work planned as part of the BGRR Decommissioning Project, the following operations may take place simultaneously:

- Regular ongoing surveys/monitoring for radiological protection of personnel working in or visiting Buildings 701, 702, 704, 708, 709, 709A, and the associated yard area.
- Removal of contaminated water from various BGRR sumps and its transfer to temporary storage at the Waste Management Facility, already analyzed by DOE's reviews of submitted safety evaluations/USQDs [18-20].
- Continuing work to prevent and eliminate the intrusion of storm water into contaminated portions of the BGRR facility.
- Unspecified activities, to immediately protect the environment from unmonitored potential or actual releases originating from the BGRR.

2.3 Inventory of Hazardous Substances

The total radiological inventory is made up of three sources: Building 701's Nuclear Material Storage Vault Inventory, BGRR's Balance-of-Plant Material-at-Risk Inventory, and Pile Material-at-Risk Inventory.

Among the non-radiological hazardous materials in the BGRR Complex are the following:

- asbestos and asbestos-containing material
- mercury
- lead shielding and lead-based paint
- polychlorinated biphenyl (PCBs)
- cadmium

2.3.1 Building 701's Nuclear Material Storage Vault Inventory

Building 701's Nuclear Material Storage Vault is a segmented and separate facility with its own PHA and BIO.

The information in Table 2.1 represents the current inventory of the vault for hazard categorization. This does not include materials present that are packaged in DOT's Type B containers or special forms (i.e., sealed sources) maintained as such.

In the PHA for Building 701's Nuclear Material Storage Vault, hazardous material (other than radiological) was identified in the current inventory; it is 3 Kg of solid enriched lithium..

Table 2.1

BUILDING 701's NUCLEAR MATERIAL STORAGE VAULT INVENTORY[1]					
Radioisotope	**Mass (gm)**	**Specific Activity (Ci/gm)**	**Activity (Ci)**	**Category 3 Threshold (Ci)**	**Category 3 Fraction %**
Am-241	6.00E-03	3.44E+00	2.06 E-02	0.52	3.96
Cf-252	3.59E-05	5.38E+02	1.93E-02	3.2	0.60
Np-237	1.22E-01	7.05E-04	1.00E-04	0.42	0.02
Th-232	5.08E+04	1.09E-07	5.56E-03	0.1	5.56
U-238	8.19E+06	3.36E-07	2.75E+00	4.2	65.48
Ra-226	1.61E+01	3.366E-02	5.90E-01	12	4.92
				Sum	80.54

[1]Based upon Quarterly Inventory Printout for 701 Nuclear Material Storage Vault [21] and subsequent documented material transfers or repackaging.

There are plans underway to relocate the entire inventory of nuclear materials from Building 701's Nuclear Material Storage Vault to other accountable storage locations on-site or to transfer it off-site as waste for final disposition. This action is scheduled to be completed by the end of October 1999, but, in any case, before any significant decommissioning work within Building 701.

2.3.2 BGRR Balance-of-Plant (BOP) Inventory

To determine conservative bounding estimates for the BGRR Balance-of-Plant radiological inventory, the history of the BGRR operations was analyzed (BNL Historical Overview, Brookhaven Graphite Research Reactor [BGRR] Fuel Operations, Accountability and Reporting, final report dated October 28, 1997) [22].

The best estimate of the inventory was developed from the calculated burn-up of the maximum number of Natural Uranium (NU) fuel slugs unaccounted for (69 from in-reactor ruptures plus 78 from reporting- and recording-errors, plus 92 from in-canal rupture = 239 slugs equivalent to 279.62 Kg), less the amount of NU recovered from D-Tanks as low-level waste (LLW) attributable to the BGRR (265 Kg).[1] This leaves a balance of 14.62 Kg (~12.5 slugs) unaccounted for (see Table 2.2 for tabulation of fuel inventory unaccounted for, which is the

[1]Records indicate approximately 265 Kg of uranium originating from the BGRR canal and water-treatment system was removed from the D-Tanks as low-level waste and transferred to a burial site.

basis for the source of the ASA BOP Inventory). While portions of the inventory were released through the stack as airborne material[2], for the sake of conservatism, all of it will be assumed to be present as BOP inventory. Based on past surveys (pre-1998), and all surveys since the current BGRR Project began (12/29/97), the inventory is in the form of low-level contamination widely dispersed throughout the reactor's air-cooling system and adjacent areas.

Table 2.2

SOURCES OF POTENTIAL BOP INVENTORY

Source	**Natural Uranium Fuel Slugs**		**Reference**
	Number of slugs	**Mass of slugs (Kg)**	
① In-reactor ruptures	69	80.73	20
② Miscellaneous errors in reporting or recording	78	91.26	20
③ In-Canal Ruptures	92	107.63	20
Sum of ①, ②, and ③	239	279.62	Calculated
Amount of Natural Uranium removed from D Tanks as low-level waste (LLW)	[~226.5]*	265	18
ASA BOP Inventory reflected in Table 2.3 (sum of ①, ②, and ③) less the recapture in D-Tanks	[~12.5]*	14.62	Calculated

*Calculated equivalent number of slugs based on actual mass of material assuming an average slug mass = 1.17 Kg.

The BGRR NU fuel-cycle and burn-up estimates of mixed fission products, actinides, and daughter products were based on a conservative model (ORIGEN 2V2.1 of 8/1/91) [20, 23]. While the cross-section library for the BGRR was not available for computer modeling, the code was executed using a cross-section library from Canadian Deuterium Uranium (CANDU) reactor that resulted in a correlation of the Pu/U ratios in both the model and historical accountability data to within a factor of 2.

Table 2.3 identifies the total estimated BGRR BOP inventory.

[2]See BNL Interim Report, Radionuclide Air Emissions at Brookhaven National Laboratory, 1948-1961, dated May 1999 by C. Meinhold, A. Meinhold, and A. Hull.

Table 2.3

BGRR BALANCE-OF-PLANT INVENTORY		
Radioisotope	**Inventory (Ci)**	**Hazard Category 3 Fraction**
003H	1.77E-02	1.77E-05
014C	6.03E-01	1.43E-03
055Fe	1.40E+03	2.60E-01
060Co	6.98E+01	2.49E-01
063Ni	2.13E-02	3.95E-06
085Kr	2.92E-01	1.46E-05
090Sr	1.35E+01	8.45E-01
090Y	1.35E+01	9.52E-03
093Zr	8.50E-04	1.37E-05
093Nbm	7.23E-04	3.61E-07
099Tc	5.95E-03	3.50E-06
113Cdm	1.28E-03	1.16E-04
125Sb	8.50E-05	7.08E-08
137Cs	1.56E+01	2.61E-01
137Bam	1.48E+01	0.00E+00
147Pm	1.87E-03	1.87E-06
151Sm	1.77E-01	1.77E-04
152Eu	3.74E-03	1.87E-05
154Eu	1.29E-02	6.46E-05
155Eu	3.32E-03	3.53E-06
226Ra	8.50E-05	7.08E-06
231Th	1.96E-04	1.63E-08
232Th	0.00E+00	0.00E+00
234Th	4.90E-03	1.75E-06
233Pa	2.55E-05	5.54E-09
234Pam	4.90E-03	3.23E-06

Radioisotope	Inventory (Ci)	Hazard Category 3 Fraction
235U	1.96E-04	4.65E-05
236U	1.45E-04	3.44E-05
238U	5.10E-03	1.21E-03
237Np	2.55E-05	6.07E-05
238Pu	9.52E-03	1.54E-02
239Pu	7.05E-01	1.36E+00
240Pu	1.33E-01	2.57E-01
241Pu	3.71E-01	1.16E-02
241Am	7.23E-02	1.39E-01
242Am	5.10E-05	6.22E-09
242Amm	5.10E-05	9.81E-05
242Cm	4.25E-05	1.33E-06
252Cf	1.53E-04	4.78E-05

No BGRR EU fuel was considered as adding to the inventory because it was not cut, lost, nor dispersed in the BGRR canal. BGRR EU fuel failures did not cause the loss of fissile material. Spent BGRR EU fuel was placed in packages in preparation for shipment or recovery.

The BOP inventory is estimated to total 1,530 Ci (including Fe-55, which has very limited dose impact and is very hard to detect due to its extremely low-energy emission); excluding this nuclide leaves an inventory of 130 Ci.

Nonradiological hazardous materials are limited to residual products previously used by maintenance personnel, past experimental or operational staff, or other end users [13, 24].

2.3.3 Pile Inventory

With all fuel elements removed and all fuel channels rodded to remove any slugs, a rough bounding estimate was made of the total activity remaining in the BGRR Pile (BNL memorandum, R. Deem to S. Moss, dated November 10, 1998, "Estimated Source Term for BGRR Graphite and Control Rods") [25]. Activation of the graphite was estimated at 2.5E-6 Ci/gm for Type A graphite, and 2.0E-6Ci/gm for Type B graphite, gamma and beta combined. The principal gamma activation radioactivity for Type A graphite comes from Cobalt-60, Europium-154, and Silver-108m. Type B gamma activation is primarily from Cobalt-60 and

Europium-154. Beta activation for both types is due to Carbon-14 and Tritium (H-3). These results assumed the BGRR was running 100% of the time at full power for its 18-years of activation. As the actual operating history included periods when the reactor was not operating at full power, these activity estimates are very conservative.

Some time before the Bioshield (including the Graphite Pile within) is sealed off from the rest of Building 701, some sampling or a survey will be needed for health-physics and waste-management characterization. Should non-invasive techniques, such as using In-Situ Object Counting System (ISOCS), prove less than completely satisfactory, any proposed invasive sampling would be reviewed against the USI process to assess it, and to determine if an amendment to the ASA need be submitted to DOE for review and approval.

However, the Pile graphite inventory is estimated at a total of <1,500 Ci, based on the above assumptions, and a total graphite weight of 1,463,550 pounds roughly split equally between Type A and Type B graphite (a conservative assumption). Also to be considered is the radiological inventory represented by the inserted control rods that was determined in Deem's memorandum (1998) to be <200 Ci, mostly of Co-60, a product of the activation of carbon steel.

2.3.4 Total Inventory

Despite the arguments made in this document to exclude the inventory in Building 701's Nuclear Material Storage Vault from the nuclear-hazard-category determination of the BGRR complex, the following total includes that inventory (as given in Section 2.3.1). However, when the Hazards Analysis of Section 3.3 is applied, the following fractions are determined for the non-segmented facility.

		Fraction of Nuclear Category 3 Threshold, %
Building 701's Nuclear Material Storage Vault Inventory @		80.54
BGRR BOP Material-at-Risk @ ±		0.00
BGRR Pile Material-at-Risk Inventory @ ±		0.00
	SUM ≈	80.54

2.4 Demographics

The size and distribution of populations are important criteria for assessing the magnitude of risk to the public from radiological releases. However, the inventories at risk, for both chemical and radiological releases, are sufficiently low such that credible release scenarios would produce only localized effects. This is consistent with the designation of "Radiological Facility," as defined in DOE-EM-STD-5502-94, *Hazard Baseline Documentation.*

2.5 Site Features

The information contained in this section was derived from various BNL Annual Environmental Reports from the last ten years.

2.5.1 Meteorology and Climate

BNL has a Meteorology Group which has kept data on the site since 1948. In addition, in 1993 a NEXRAD meteorology facility began operation at BNL, expanding the capability of gathering meteorological information for the BNL area.

The general region experiences a combination of maritime- and continental-exposure, maritime along the coast, gradually changing to continental inland. On a broad scale, the weather is greatly influenced by the Atlantic Ocean, Long Island Sound, and various bays. The presence of these water bodies and associated land units moderates both summer- and winter-temperatures, and strongly influences wind and humidity patterns. These factors also greatly reduce the snowfall in the BNL area from that expected further inland from the more continental environment. BNL can be characterized, like many eastern seaboard areas, as well-ventilated by winds from all directions with rapid, fairly consistent alternations among various types of atmospheric stability.

2.5.2 Temperature

The annual average temperature is approximately 9.5°C, which is higher than most places of the same latitude within the United States, except along the Pacific Coast. Winter temperatures are milder because of the surrounding warmer water. During the summer, afternoon temperatures are moderated by local sea breezes blowing on-shore from the cool water-surfaces. However, temperatures on-site have been recorded as high as 38°C in July to as low as -37°C in January. Figure 2.2 shows the monthly average temperatures in 1997, and is typical of historical temperature data. Rapid extremes in winter temperatures that melt snow and ice, would not flood the BGRR facility due to its elevation and the grading around the facility [26].

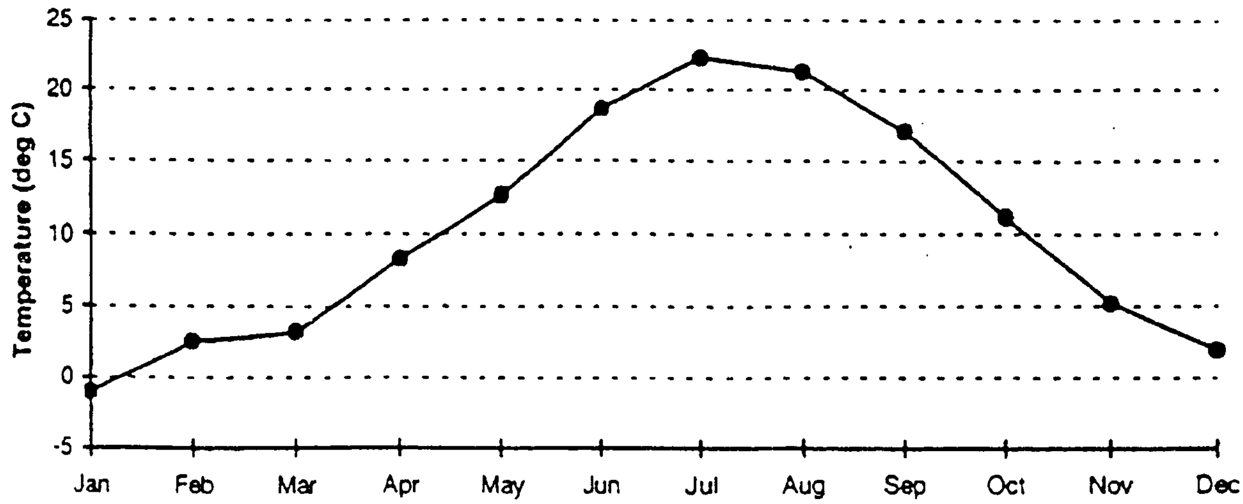

Figure 2.2. 1997 Monthly Average Temperature Trend

2.5.3 Precipitation

The average annual precipitation is approximately 48.8 inches, with little variation in the monthly averages. Warm season precipitation is primarily convective, whereas most late fall and winter precipitation results from storms moving northeastward along or near the east coast. An hourly rainfall rate of more than 2 inches and a 24-hour rainfall rate of 8 inches is exceptional but not unknown. Thundershowers have occurred during every month, but are most prevalent during the summer. Because of the proximity of the ocean, storms are generated over inland areas around midday and are carried to eastern Long Island by upper-level wind flow. Average relatively humidity is 74% annually, with a high of 82% during August and September, and a low of 66% in March.

Snow falls between October and April. The seasonal amount averages 31.6 inches, but varies greatly from year to year, e.g., 30.5 cm were recorded during 1997-98, and 102 inches during 1995-96. The mean annual number of days with freezing rain or freezing drizzle is six. Heavy ice storms are infrequent and generally occur in January. The total precipitation for 1997 was 41 inches, which is about 8 inches below the 40-year annual average. Figures 2.3 and 2.4, respectively, show the 1997 monthly and historic precipitation data. On average, about half of the annual precipitation is lost to the atmosphere through evapotranspiration, and the other half percolates through the soil to recharge groundwater.

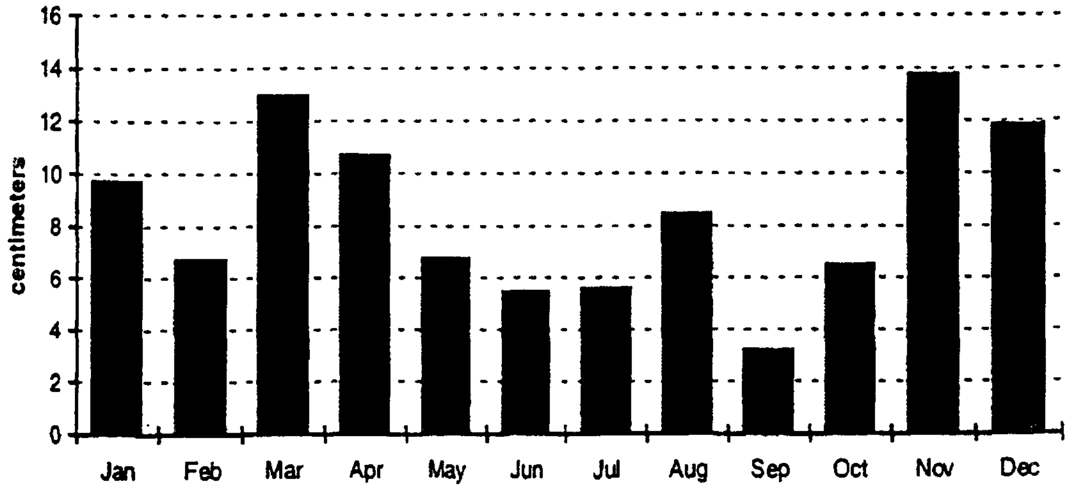

Figure 2.3. 1997 Monthly Precipitation

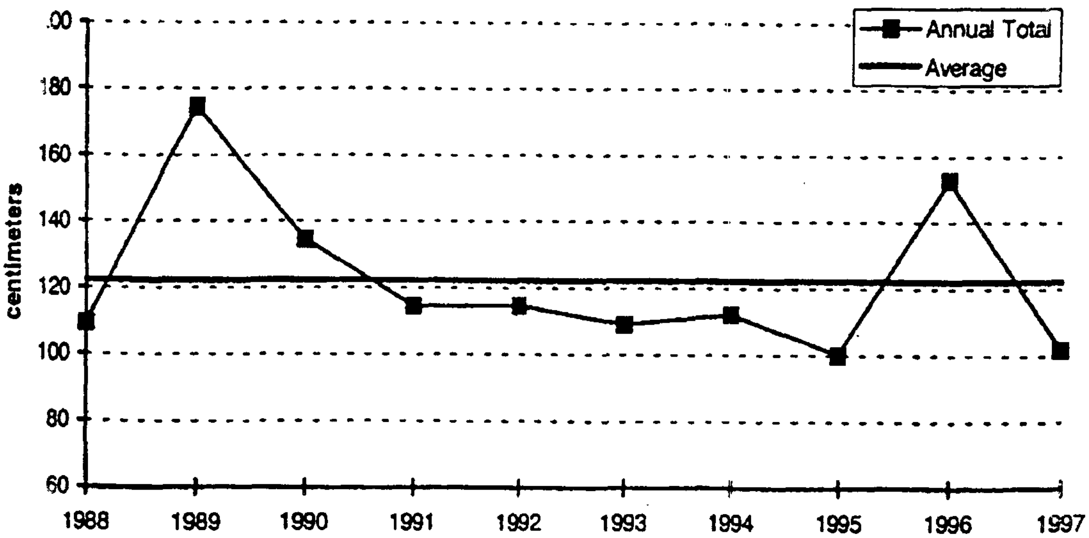

Figure 2.4. 10-Year Precipitation Trend

The roof structure of the BGRR facility is designed for a snow loading of 40 pounds per square foot. A worst-case snowstorm would not damage the structure.

Grading around the BGRR is such that runoff will be away from the facility to protect against internal flooding of the facility precipitation and melting snow.

2.5.4 Prevailing Winds

The prevailing ground-level winds are from the southwest during the summer, from the northwest during the winter, and about equally from these two directions during the spring and fall. Figure 2.5 shows the annual wind rose for calendar year 1997 at the 290-foot level.

"Nor'easters" can occur from December through March, bringing winds of 80 to 90 mph. The probability during September for at least one tropical cyclone somewhere in the North Atlantic is 92%, with a 42% chance of three or more storms occurring. In recent decades, hurricanes have moved inland or passed close enough off-shore to result in storms of hurricane winds, heavy rainfall, or high storm tides. Tornados occur, on average, at least once per year.

The highest wind speeds at BNL have occurred with hurricanes which occur from June to October, and a few weak or declining storms in May and November. In September, the chances are 92% for at least one tropical cyclone somewhere in the North Atlantic and 42% for three or more. The northeastern states experienced hurricanes of moderate intensity only rarely between 1901 and 1931. Sections of the coast have been severely affected since 1932, with several hurricanes moving inland or passing close enough offshore to result in storms of hurricane winds, heavy rainfall, or high storm tides. However, tornados and hail storms are extremely rare on Long Island.

Even if there was a high-wind event, it would be bounded by the analysis of hurricane winds up to 110 mph, which were evaluated in the "Brookhaven National Laboratory, FASTER Team, BGRR Hazards Summary and Recommendations Document (Draft)" [27]. The analysis showed that any such events are not expected to have any impact which would release the radiological inventory of the BGRR facility.

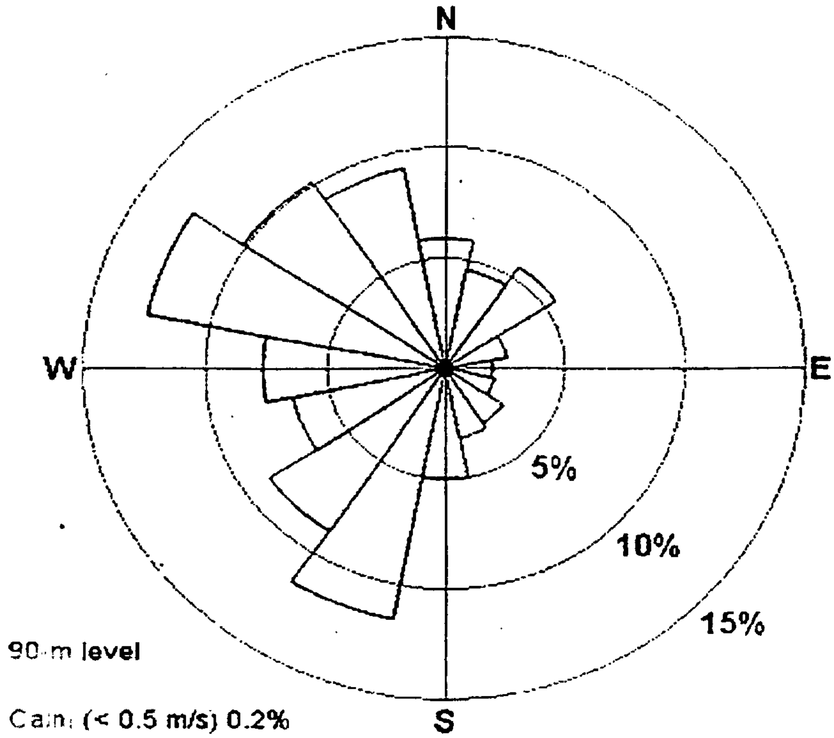

Figure 2.5. Annual Wind Rose for Calendar Year 1997

2.5.5 Hydrology Description

Studies of Long Island hydrology and geology near BNL indicate that the uppermost Pleistocene deposits, which are between 102 to 200 feet thick, are generally sandy and highly permeable. Water penetrates these deposits readily and there is little direct runoff into surface streams, except during periods of intense precipitation. On the average, about half of the annual precipitation is lost to the atmosphere through evapotranspiration and the other half percolates through the soil to recharge groundwater. Runoffs form a very insignificant portion of the total rainfall, usually less than 2%. BNL lies on the western rim of the shallow Peconic River watershed. The marshy areas in the north and eastern sections of the site are a portion of the Peconic River headwaters. The Peconic River both recharges and receives water from the groundwater aquifer depending on the hydrogeological potential. In time of drought, the river water typically recharges to groundwater, while during normal to above normal precipitation, the river receives water from the aquifer.

2.5.6 Floods

The only water of any potential significance on the BNL site is the Peconic River, on the north-northeast side of the site. The Peconic here is frequently dry, and there is no record of the river producing any flooding that could encroach on the BNL site. Therefore, flooding from surface-water sources is not considered a concern.

As evidenced in the *Brookhaven National Laboratory Site Environmental Report for Calendar Year 1993* [28], there is a potential for the groundwater to rise to the surface in certain areas of BNL and according to this report, it has done so. Groundwater is generally 35- to 40-feet below ground surface around the BNL site, and therefore, flooding is not considered a threat.

While BNL is relatively near the coast, no Tsunami flooding of the area has been recorded. While there can be mild ice-rain near BNL, it is not expected that the site will experience any severe ice jam, flood, wind-driven ice ridges, nor ice-produced forces that would affect the BGRR facility.

The BGRR facility is located at a high point on the BNL site. The base of the building is 134-feet above sea level. Flooding is not considered a major threat to the BGRR facility due to the sites characteristics and the elevation of the facility.

2.5.7 Geology and Seismology

BNL is located on Long Island which, as a whole, is the terminal moraines of the last two glaciations. The BNL site is in the upper part of the Peconic River Valley, which is bordered by two lines of low hills. These extend east and west beyond the limits of the valley nearly the full length of Long Island, and form its most prominent topographic features. The northern line of hills, known as the Harbor Hill moraine, lies along the north shore, and the southern line, the Ronkonkoma moraine, extends along the center of Long Island and passes just south of BNL.

Just west of the BNL site, the two moraines are connected by a narrow north-south ridge. East of this ridge, and enclosed by it and the two moraines, is the Manorville basin; the main BNL grounds are on the basin's relatively high west margin. The basin forms the upper drainage area of the Peconic River.

Six principal stratigraphic units, some of which include subdivisions of minor importance, were recognized in the test drilling at BNL. At the base is the oldest unit, the bedrock of the Pre-Cretaceous age, which has no formational name. Above the bedrock is the Raritan formation of Cretaceous age, which is as much as 500-feet thick and has two members: the lower, as much as 300-feet thick, is called the Lloyd sand member and is composed of coarse-grained sand, gravel, and some clay; the upper, about 200-feet thick, is mostly clay and is called the clay member. Overlying the Raritan formation is the Magothy formation, also of Cretaceous age. Beneath BNL, this formation consists of about 900-feet of mostly clayey sand, and it includes beds of clay, and of sand and gravel. Under most of the BNL tract, and, in general, under the southern half of central Suffolk County, the Magothy formation is overlain unconformably by the Gardiners Clay of Pleistocene age. The sixth major stratigraphic unit is called the upper Pleistocene deposits, an informal term for the glacial deposits which, in nearly all of Long Island, overlie the Gardiners Clay of the Magothy formation. Most of these deposits consist of sand and gravel which, with local silt and clay, form the stratified outwash and morainal deposits of presumed Wisconsin age. Their maximum known thickness is about 200 feet. Most of the formations recognized here occur nearly everywhere beneath Long Island.

The bedrock underlying the unconsolidated deposits, as deep as 1,600 feet beneath BNL, includes hard dense schist, gneiss, and granite similar to that underlying much of the mainland in nearby parts of New York and Connecticut.

In recorded history (since 1638), the closest earthquakes of any significance occurred in 1929 at Attica, New York, with a Mercalli intensity of IX (with a maximum acceleration of 0.3 to 0.7 g), and in 1931 at Lake George, New York, with a Mercalli intensity of VII (with a maximum acceleration of 0.07 to 0.22 g). Attica is located 350 miles northwest of Long Island, and Lake George is approximately 250 miles north.

The BNL site was originally designated as a "moderate" seismicity zone as per *Interagency Committee on Seismic Safety in Construction (ICSSC) Technical Report 17, Appendix A* [29]. This ICSSC report designates a "moderate" zone as one having an acceleration velocity of between 0.10 g and 0.20 g, with a "low" zone being below 0.10 g. A more detailed analysis was made using the county-by-county maps from the 1994 *NEHRP Recommended Provisions for the Development of Seismic Regulations for New Buildings* as allowed by the ICSSC report. This evaluation shows that BNL falls into an area where the acceleration velocity is slightly less than 0.10 g, and thus reclassified as a "low" seismicity zone. This classification has been agreed to by DOE during the recent project implementing Executive Order 12941, "Seismic Safety of Existing Federally Owned or Leased Buildings," and documented in BNL memorandum, DeBobes to Helms dated May 28, 1998, "Phase 2, 3, and 4 submittal for Executive Order 12941."

There are no active faults known in the Long Island area, and earthquake intensities greater than III (with a maximum acceleration of 0.003 to 0.007 g) (Brookhaven National Laboratory Hazard Assessment Document, Rev. 1, December 1997) have not been recorded. Furthermore, ER-83 (of DOE) concluded that BNL could be considered a low-seismicity zone for the purpose of completing EO 12941 activities, based on an examination of NEHRP Map 4. The objective of the EO 12941 program was to identify buildings with potential concerns about life-safety or the release of hazardous materials, and to estimate the approximate costs of rehabilitating deficient buildings.

The probability of an earthquake in the BNL area sufficiently intense to damage buildings and reactor structures was thoroughly investigated during construction of the Graphite Reactor [30] and several subsequent reviews of the High Flux Beam Reactor. The consensus of seismologists is that no significant quakes are to be expected in the foreseeable future. No active earthquake-producing faults are known in the Long Island area.

3.0 HAZARD ANALYSIS

Section 3 provides the history, current analysis, and outcome of the hazards assessment, hazard analysis, and results of the various safety basis reviews that have been undertaken at the BGRR since April 1998. This section is arranged in the following order to set the basis and provide the outcome of these analyses:

- Section 3.1 discusses the PHA and Preliminary Hazards Classification (PHC) that established the basis, origin, and foundation of the BGRR Decommissioning Project safety basis work performed since early 1998.

- Section 3.2 describes the method for the hazard analysis to be used in Section 3.2.1 as defined by BNL ES&H Standard 1.3.3 [12]. Sections 3.2.2 through 3.2.9 performs the analysis for each of the seven accidents described in the PHA / PHC, and one additional accident (008) that was added as part of the review cycle for the ASA. Each of these analyses defines the probability and severity of the pre- and post-mitigation accidents to arrive at a Risk Category as defined in Table 3.4.

- Section 3.3 summarizes the worst-case consequences from the eight accidents analyzes in Section 3.2, and describes the bounding dose accident.

- Section 3.4 collects the results of the eight analyses and compares those results with the requirements in the DOE *Hazard Baseline Documentation* [5] and DOE-STD-1027-92 [4] to define the hazards classification for the BGRR facility during the Decommissioning Project for the authorized work.

3.1 Preliminary Hazard Analysis

In developing the authorization basis, a PHA was performed for the BGRR facility [27, 31]. It considered the entire facility in its current configuration, except for the 701 Nuclear Material Storage Vault. The vault was excluded since there was a separate PHA for that area, and, more importantly, the inventory of materials in the vault are segmented from the BGRR facility. The original analysis relied upon the information available and expertise of the hazard-analysis team, which included reactor systems- and ES&H-subject-matter experts. Consistent with DOE's guidance on developing authorization-basis documents, the hazard analysis evaluated both externally driven events and those related to work in the facility and their potential impacts on target receptors. These receptors included on- and off-site personnel, the environment, and facility workers. Based on a preliminary evaluation <u>no significant quantities of non-radiological hazardous material were identified, and consequently, the PHA focused on the radiological consequences of the identified events.</u>

Since the objective of an interim-authorization-basis document is to provide a means for the continued authorization of operations within the BGRR facility, the hazard analysis was planned to be a broad-brush analysis of hazards and potential accidents. Furthermore, the PHA process was selected on its ability to generate recommendations that could eliminate or reduce the risks associated with the facility.

The hazard-analysis team identified hazards and evaluated the possible causes and effects of potential scenarios involving them. Consistent with the PHA approach, they did not develop an exhaustive list of causes; rather, they listed sufficient causes to judge the credibility of the accident. The seven accidents developed by the team are shown below. An eighth accident was added in response to subsequent reviews (further explained in Section 3.2.9):

- 001 Seismic Event
- 002 High Winds
- 003 Graphite Dust Detonation
- 004 Loss of Pile Negative-Pressure System Ventilation
- 005 Loss of Pile Negative-Pressure System Filtration
- 006 Crane Load Drop
- 007 Fire
- 008 Facility Workers' Exposure to Toxic Material

The team then assessed the effects of each scenario, limiting them to realistic but conservative impacts. In this way, a credible list of bounding scenarios was established. They are considered bounding, based on the associated overall risk of each one.

The following assumptions were made in evaluating all the BGRR unmitigated accident scenarios identified. These assumptions ensured that the analysis was conservative, and that it gave a technically bounding set of scenarios in the authorization-basis document:

- The entire inventory was considered at risk for every unmitigated scenario.

- The evaluation of each unmitigated scenario assumed worst-case conditions for the entire inventory, its location, form, and distribution.

3.1.1 Preliminary Hazard Classification

The gross inventories, discussed in Section 3.1, were compared to the threshold quantities (TQs) in DOE-STD-1027-92 [4] and the reportable quantities (RQ) in 40CFR302.4 and 40CFR68.130 to determine the Preliminary Hazard Classification (PHC) [27]. The PHC for the BGRR facility was determined to be Nuclear Hazard Category 2.

3.2 Risk Assessment

3.2.1 Method of Risk Assessment

The risk assessment of the BGRR was based on a methodical review of each initiating event and the severity, probability, and risk category of the corresponding hazards associated with the facility as originally defined by the PHA. Only one accident-initiating event is postulated to occur at one time. Several working sessions were held at BNL where all the accident scenarios were listed and analyzed by the working group supporting the PHA undertaken by the independent reactor-systems and ES&H-subject-matter experts. In subsequent reviews of related draft documents and earlier versions of this document, non-credible and nonhazardous events were eliminated, while those that were retained had post-mitigation parameter values added to them; pre-mitigation parameter values also were refined as more and better information became available. The risk-assessment tables which follow, and are summarized in Section 3.4, represent the final determination of the extent of the hazards associated with the BGRR facility in its current state.

BNL's ES&H Manual Standard 1.3.3, "Safety Analysis Reports/Safety Assessment Documents," [12] provides the methodology for examining the safety of facilities at the BNL. It has guidance for assessing the appropriate level of severity, probability, and risk. Table 3.1 depicts the form used in this report to perform the risk assessment and used in this safety analysis. Tables 3.2 through 3.4 summarize the Risk Assessment Matrix found in Standard 1.3.3 and used here.

Table 3.1

RISK ASSESSMENT FORMAT						
Severity	I ( ) Catastrophic	II ( ) Critical	III ( ) Marginal	IV ( ) Negligible		
Probability	A ( ) Frequent	B ( ) Probable	C ( ) Occasional	D ( ) Remote	E ( ) Extr Remote	F ( ) Impossible
Risk Category	1 ( ) High	2 ( ) Moderate	3 ( ) Low	4 ( ) Routine		

Table 3.2 summarizes the potential consequences of hazards falling into the four severity classifications established by BNL's ES&H Standard 1.3.3. Standard 1.3.3 considers consequences for the following:

- Non-radiation release/exposure, on-site/off-site
- Radiation release/exposure, on-site/off-site
- Equipment loss
- Program downtime
- Program compromise
- Public-impact perception

Table 3.2

HAZARD SEVERITY		
Category	**Descriptive Word**	**Potential Consequences**
I	Catastrophic	May cause death or system loss. > 100 rem Committed Effective Dose Equivalent (CEDE) on-site or > EPA Protective Action Guidelines off-site. {>$1,000,000; >4 months}
II	Critical	May cause severe injury, severe occupational illness, or major system damage. >25 rem CEDE on-site or 10 mrem off-site. {>$250,000; >3 weeks or <4 months}
III	Marginal	May cause minor injury, minor occupational illness, or minor system damage.> 5 rem annual limit on-site. {>$50,000; >4 days or <3 weeks}
IV	Negligible	Will not result in injury, occupational illness, or system damage. > 3 rem admin annual limit or 1 rem admin quarterly limit. {<$50,000; <4 days}

Table 3.3 summarizes the probability categories established by BNL's ES&H Standard 1.3.3. They are based on the likelihood of the potential consequences occurring for a given hazard.

Table 3.3

HAZARD PROBABILITY		
Category	**Descriptive Word**	**Potential Consequences**
A	Frequent	Likely to occur repeatedly during life cycle of system.
B	Probable	Likely to occur several times in life cycle of system.
C	Occasional	Likely to occur sometime in life cycle of system.
D	Remote	Not likely to occur in life cycle of system, but possible.
E	Extremely Remote	Probability of occurrence cannot be distinguished from zero.

Table 3.4 summarizes the risk categories established by BNL's ES&H Standard 1.3.3. Choosing a severity and a probability for a given hazard determines its risk category. Standard 1.3.3 establishes the documentation and minimum approval required for each category.

Table 3.4

RISK CATEGORY						
Hazard Severity	**A Frequent**	**B Probable**	**C Occasional**	**D Remote**	**E Extremely Remote**	**F Impossible**
I Catastrophic	1. High	1. High	1. High	2. Moderate	3. Low	4. Routine
II Critical	1. High	1. High	2. Moderate	3. Low	3. Low	4. Routine
III Marginal	2. Moderate	2. Moderate	3. Low	3. Low	4. Routine	4. Routine
IV Negligible	4. Routine	4. Routine	4. Routine	4. Routine	4. Routine	4. Routine

Hazard mitigation takes the form of engineered features, administrative controls, operator training, or a combination of these. Generally, the hazard's severity is not changed by mitigation, but its probability is reduced.

Risk Assessment for the facility is given on the following pages where operator's error, equipment/system failure, an accident or natural phenomenon is the initiating event. Each event is analyzed on four tables: Hazard, Risk Assessment Before Mitigation, Hazard Mitigation, and Risk Assessment After Mitigation.

The Hazard table first identifies the initiating event and lists its possible consequences and its specific hazards. A list of potential initiators is given.

The Hazard-Mitigation table lists the administrative controls, training, and engineered features that will mitigate the effects of the event. The Risk-Assessment tables contrast the risk involved due to an initiating event with and without mitigation.

3.2.2 Risk Assessment No. 001 covering 0.15 g Seismic Event

SYSTEM: BGRR Facility **NUMBER:** 001
HAZARD: Seismic Event

Event:	0.15 g Seismic Event
Possible Consequences & Hazards:	Damage to facility structures / equipment. Release of radiation / radioactive materials to environment. Exposure to radioactive materials through ingestion, inhalation, or dermal exposure. Building- or room-contamination. Program delays / interruptions
Potential Initiators:	Seismic activity

Risk Assessment Prior to Mitigation

Severity:	I ( ) Catastrophic	II ( ) Critical	III ( ) Marginal	IV (X) Negligible		
Probability:	A ( ) Frequent	B ( ) Probable	C ( ) Occasional	D (X) Remote	E ( ) Extr Remote	F ( ) Impossible
Risk Category:	1 ( ) High	2 () Moderate	3 ( ) Low	4 (X) Routine		

Hazard Mitigation:	Limited radiological inventory at risk and available for release from entire facility (<Nuclear Hazard Category 3 Threshold), in considering the activities covered by this ASA. Additional limitation on fraction of entire facility's inventory available for release, due to the strength of the Bioshield and the physical forms and distribution of inventory materials. Lightweight-roof structural surface minimizing the impact of failure. Building structures' design-criteria comply with AEC's requirements (including main-floor design-loading of 500 lbs/ft^2, intermediate/upper floor design-loading of 125 lbs/ft^2; concrete slabs at base of each window bay design loading of 300 lbs/ft^2; experimental balconies design-loading of 1,000 lbs/ft^2).

Risk Assessment Following Mitigation

Severity	I ( ) Catastrophic	II ( ) Critical	III ( ) Marginal	IV (X) Negligible		
Probability	A ( ) Frequent	B ( ) Probable	C ( ) Occasional	D ( ) Remote	E (X) Extr Remote	F ( ) Impossible
Risk Category	1 ( ) High	2 ( ) Moderate	3 () Low	4 (X) Routine		

Description - 0.15 g Seismic Event

Hazard Probability (as defined in Table 3.3)

The probability of an earthquake in the BNL area sufficiently intense to damage buildings and reactor structures was thoroughly investigated during construction of the Graphite Reactor [30] and several subsequent reviews of the High Flux Beam Reactor. The consensus of seismologists is that no significant quakes are to be expected in the foreseeable future. No active earthquake-producing faults are known in the Long Island area.

For these reasons, the unmitigated probability conservatively assigned to a 0.15 g seismic event was **REMOTE** (not likely to occur in life cycle of system, but possible).

In considering the mitigation factors listed on Risk Assessment No. 001, and the limited life-cycle remaining, the post-mitigation probability is reduced to **EXTREMELY REMOTE** (probability of occurrence cannot be distinguished from zero).

Hazard Severity (as defined by Table 3.2)

Because the BNL area experiences high winds (e.g., Atlantic coast hurricanes), buildings on the site (including the BGRR Complex) were designed for significant wind loads and have no history of major lateral structural damage from high winds or wind gusts. Significant earthquake damage should not occur for such buildings at low seismicity sites, such as BNL.

Since the BGRR was defueled and shut down approximately 30 years ago, there have been no programmatic delays nor repair costs associated with minor damage caused by a seismic event. Personnel are not assigned to the BGRR Complex, other than a few temporary decommissioning staff currently located in office space in Building 701; hence, there is only a small potential for occupational illness or injury.

Surveys conducted at the BGRR have not shown any high radiation in generally accessible areas, suggesting that the BOP inventory is not concentrated in, nor adjacent to, these normally accessible areas. It supports the assumption that, in general, the BOP inventory is relatively well distributed. It is further assumed that most of the BOP inventory is located in the BGRR facility's air-cooling system (mostly below-grade in the pre-filter ductwork), and the Canal/Water Treating system (mostly below-grade). Some minor amount of the remaining BOP inventory is dispersed in soils and structures in and around the 701 Building. For the accidents which potentially could impact the BOP inventory (001 Seismic Event, 002 Hurricane Winds, 006 Crane Load Drop, and 007 Fire) only a fraction of the total BOP inventory would be involved. For instance, an earthquake or hurricane might cause the above-grade ducts to fail, but the below-grade filters and canal inventory would be unaffected. Similarly, the volume of materials that could be lifted by the Building 701's 10-ton crane or consumed in a fire limits the total radioactive inventory that could be involved.

In addition, of that portion of the BOP inventory that could be affected in any accident, only a fraction can reasonably be expected to be released and contribute to any dose. The fixed, painted on, or solid radioactive material should be expected to remain in the rubble pile that results from the accident. Therefore, when the percentage of BOP inventory affected is multiplied by the percentage of that inventory in a physical form that could be released, the result is the material available to contribute to a dose. This comparison is the basis for a conservative estimate, based on the best engineering judgment that no credible single accident should release more than 15% of the BOP inventory assessed on the work scope identified in Section 1.4. This value represents a maximal potential dose of less than 5 rem effective whole body dose where exposure is at 30 meters for 1 day of inhalation and direct exposure, and longer for the ingestion pathway, assuming that all released inventory were emitted instantaneously from one point (see Attachment 1 of DOE-STD-1027-92).

These potential consequences most closely correspond to the definition of Hazard Severity IV - **NEGLIGIBLE** (per Table 3.2, Hazard Severity).

Risk Category (as defined by Table 3.4)

Both the pre-mitigation combination of Severity = **NEGLIGIBLE** with Probability = **REMOTE,** and the post-mitigation combination of Severity = **NEGLIGIBLE** with Probability = **EXTREMELY REMOTE,** define the risk category as **ROUTINE**, for the work planned under this ASA.

3.2.3 Risk Assessment No. 002 covering 110-mph Hurricane Winds

SYSTEM: BGRR Facility **NUMBER:** 002
HAZARD: High Winds

Event:	110 mph Hurricane Winds
Possible Consequences & Hazards:	Wind-generated missile strikes. Damage to building's housing facility and internal structures / equipment. Loss of containment for radioactive materials. Release of radioactive materials to the environment. Exposure to radioactive materials.
Potential Initiators:	Tornado, hurricane, and related natural phenomenon.

Risk Assessment Prior to Mitigation						
Severity:	I ( ) Catastrophic	II ( ) Critical	III ( ) Marginal	IV (X) Negligible		
Probability:	A ( ) Frequent	B ( ) Probable	C (X) Occasional	D ( ) Remote	E ( ) Extr Remote	F ( ) Impossible
Risk Category:	1 ( ) High	2 ( ) Moderate	3 ( ) Low	4 (X) Routine		

Hazard Mitigation:	Limited radiological inventory at risk and available for release from entire facility (<Nuclear Hazard Category 3 Threshold), considering the activities covered by this ASA. Additional limitation on fraction of entire facility's inventory available for release, due to the strength of the Bioshield and the physical forms and distribution of inventory materials. Lightweight-roof structural surface minimizing impact of failure. Building structure's design-criteria comply with AEC's requirements (including main floor design-loading of 500 lbs/ft^2, intermediate/upper floor design loading of 125 lbs/ft^2; concrete slabs at base of each window bay design- loading of 300 lbs/ft^2; experimental balconies design-loading of 1,000 lbs/ft^2).

Risk Assessment Following Mitigation						
Severity:	I ( ) Catastrophic	II ( ) Critical	III ( ) Marginal	IV (X) Negligible		
Probability:	A ( ) Frequent	B ( ) Probable	C ( ) Occasional	D (X) Remote	E ( ) Extr Remote	F ( ) Impossible
Risk Category:	1 ( ) High	2 ( ) Moderate	3 ( ) Low	4 (X) Routine		

Description - 110 mph Hurricane Winds

Hazard Probability (as defined in Table 3.3)

Although uncommon, maximum wind speeds of 80- to 90-mph can be expected on Long Island. The highest wind speeds recorded at BNL occurred during hurricanes. On August 31, 1954, estimated 125-mph winds were experienced during Hurricane Carol. Hurricanes can occur in June through October, with a few weak or declining storms in May and November.

The probability of a hurricane striking this area in a given year is between 0 and 1%. According to the Federal Emergency Management Agency (FEMA), the probability of a Category IV or V hurricane (defined by the Saffir Simpson scale) with winds in excess of 125-miles per hour is close to zero. This is supported by records from 1954 to date, maintained by BNL's Department of Applied Science.

For these reasons, the unmitigated probability conservatively assigned to 110-mph hurricane-winds was **OCCASIONAL** (likely to occur sometime in life cycle of system).

Considering the mitigation factors listed on Risk Assessment No. 002, and the limited life cycle remaining, the post-mitigation probability is reduced to **REMOTE** (not likely to occur in life cycle of system, but possible).

Hazard Severity (as defined by Table 3.2)

As discussed above and under Risk Assessment No. 001, the BNL area experiences high winds (e.g., Atlantic coast hurricanes), so buildings on the site (including the BGRR Complex) were designed for significant wind-loads and have no history of major lateral structural damage from high winds or wind gusts.

Since the BGRR was defueled and shut down approximately 30 years ago, no programmatic delays or repair costs have been associated with minor damage caused by any high winds. No personnel are assigned to the BGRR Complex, other than a few temporary decommissioning staff located in office space in Building 701; hence, there is only a small potential for occupational illness or injury.

The limited radiological material subject to release, conservatively estimated at less than 15% of the BOP inventory (detailed under Seismic Event-Risk Assessment No.1), represents a maximal potential dose of less than 5 rem effective-whole-body dose where exposure is at 30 meters for one day of inhalation and direct exposure, and even longer for the ingestion pathway, if all inventory were located at one point and simultaneously released (based on Attachment 1 of DOE-STD-1027-92).

These potential consequences most closely correspond to the definition of Hazard Severity IV - **NEGLIGIBLE** (per Table 3.2, Hazard Severity).

Risk Category (as defined by Table 3.4)

Both the pre-mitigation combination of Severity = **NEGLIGIBLE** with Probability = **OCCASIONAL**, and the post-mitigation combination of Severity = **NEGLIGIBLE** with Probability = **REMOTE** define the Risk Category as **ROUTINE**, for the activities under this ASA.

3.2.4 Risk Assessment No. 003 covering Graphite Dust Detonation

SYSTEM: BGRR Facility **NUMBER:** 003
HAZARD: To On-site Personnel, Equipment

Event:	Graphite-Dust Detonation
Possible Consequences & Hazards:	Fire / Blast Wave Contamination of building's housing facility and internal structures / equipment Radiation exposure to on-site personnel Release of radioactive materials/ radiation to the environment Exposure to radioactive materials through ingestion, inhalation, or dermal exposure.
Potential Initiators:	Direct electrical short to ground, combined with a specific airborne concentration of particular sized particles of graphite dust inside the Bioshield.

Risk Assessment Prior to Mitigation

Severity:	I ( ) Catastrophic	II ( ) Critical	III (X) Marginal	IV ( ) Negligible		
Probability:	A ( ) Frequent	B ( ) Probable	C ( ) Occasional	D ( ) Remote	E (X) Extr Remote	F ( ) Impossible
Risk Category:	1 ( ) High	2 () Moderate	3 ( ) Low	4 (X) Routine		

Hazard Mitigation:	Limited radiological inventory at risk and available for release from entire facility (<Nuclear Hazard Category 3 Threshold), in consideration of the activities covered by this ASA. Additional limitation on fraction of entire facility's inventory available for release due to graphite detonation as a result of the strength of the Bioshield and the physical forms and distribution of inventory materials. Enhanced stabilization of Reactor Pile, including, but not limited to, isolation of sources of electrical power inside the Bioshield. Limitations on uncontrolled torch-cutting in BGRR Facility. Lack of sufficient airborne loading and heating (as analyzed) of required sized graphite particles and limitations on production of same [32]. Building protected against lightning by proximity of Reactor stack.

Risk Assessment Following Mitigation

Severity:	I ( ) Catastrophic	II () Critical	III (X) Marginal	IV ( ) Negligible		
Probability:	A ( ) Frequent	B ( ) Probable	C ( ) Occasional	D ( ) Remote	E ( ) Extr Remote	F (X) Impossible
Risk Category:	1 ( ) High	2 ( ) Moderate	3 () Low	4 (X) Routine		

Description - Graphite Dust Detonation

Hazard Probability (as defined in Table 3.3)

A graphite-dust explosion was considered to be an incredible event for the Hanford N Reactor [33]. The National Fire Protection Association (NFPA) (Fire Protection Handbook, 18th Edition, Chapter 3, Fire Prevention, Table 3-27B, "Explosion Characteristics of Various Dusts," National Fire Protection Association [34]) has a handbook that discusses dusts and their potential for explosion. A table lists graphite as "not ignitable." However, Factory Mutual Engineering Association conducted sixteen tests on graphite powder and found that median-sized particle, 128-microns or smaller, can be ignitable (Proprietary Information, personal communication). Larger particles have a lower potential for ignition.

Graphite is considerably more difficult to ignite and burn than coal, coke, or charcoal. Graphite has a much higher thermal conductivity, therefore it dissipates the heat produced by burning; and consequently, it is more difficult to keep hot. Coals, cokes, and charcoals develop a porous white ash on their burning surfaces which greatly reduces radiative-heat losses while simultaneously allowing air to reach the carbon surfaces and maintain burning. Also, they are heavily loaded with impurities which catalyze oxidation. Nuclear-grade graphite is one of the purest substances produced in massive quantities. For these reasons graphite dust sometimes is used as a fire-suppressant.

Of the sixteen samples tested by Factory Mutual, none were ignited with small sources, such as a 100-joule electric match or a glowing Nichrome wire. Hence, ordinary electrical equipment would not be an ignition source, nor would static sparks and "grinding wheel" sparks. The dust needs to be exposed to an open flame, welding torch, or full 120-volt circuit- short to start burning.

Graphite dust can only explode if the airborne concentration is very high and particle size very small (<128 microns). While high airborne loadings conceivably could be created for short periods by mechanically stirring up dust which may be present, such loading cannot be sustained because the dust settles out. There is no evidence that the air in the biological shield has a high graphite-dust loading. If this were so, the dust would be entrained by the ventilation stream and deposited on the exhaust filter. To date, no radiation above background has been detected on expended filters. Therefore, no significant airborne loading of activated graphite dust routinely exists within the Bioshield.

For these reasons, the unmitigated probability conservatively assigned to Graphite Dust Detonation was **EXTREMELY REMOTE** (probability of occurrence cannot be distinguished from zero).

Taking into account the mitigation factors listed on Risk Assessment No. 003, and the limited life-cycle remaining, post-mitigation probability is reduced to **IMPOSSIBLE** (physically impossible to occur).

Hazard Severity (as defined by Table 3.2)

The Factory Mutual tests of the graphite dust indicated that such explosions generated only a moderate power. As the Pile's negative-pressure systems maintain the air pressure within the Bioshield slightly below that outside, any moderate pressure has ample relief capabilities, without damaging either the Pile or the Bioshield.

Since the BGRR was defueled and shut down approximately 30 years ago, there are no programmatic delays or repair costs associated with minor damage caused by detonation of graphite dust. Since personnel are not assigned to the BGRR Complex, other than a few temporary decommissioning staff located in office space in Building 701, the potential for occupational illness or injury is small. However, in this particular case, the potential initiator implies the presence nearby of decommissioning worker(s), so minor injury is a possibility.

Because this event does not depend on the BOP's radiological inventory, an alternate estimate of radiological impact was needed. In the absence of detectable airborne levels of activated graphite on the replaceable HEPA exhaust-filters, the minimum adequate explosive concentration of activated dust will be the maximum inventory assumed present and available for dispersion.

Based on Table 4.15A, Explosion Characteristics of Various Dusts, of NFPA Handbook, and, in the absence of any other reasonable values specifically for Graphite Dust, the Minimum Explosive Concentration for Carbonaceous Dusts (55-140 g/m^3) shall be used for these estimates. (While much higher values of graphite dust concentration are believed to be required for an explosion, the apparent absence of such concentrations negates the value of such estimates being used for this determination.) The estimated free volume inside the Bioshield is estimated at 558 m^3, less the volume of the Pile and not including any portion of the plenum. This represents a dispersible graphite inventory of 30,690 to 78,120 gm.

In section 2.3.3, Pile Inventory, Type A graphite (the more active of the two types analyzed) was estimated at residual activation levels of 2.5E-6 Ci/gm. The gamma activity comes primarily from Co-60, Eu-154, and Ag-108m with beta activity from C-14 and H-3. For 30,690 to 78,120 gm at 2.5 E-6 Ci/gm, this is between 0.07672 and 0.1953 Ci.

Isotope	Category 3 Threshold Activity, Ci
H-3	1,000
C-14	420
Co-60	5,600
Ag-108m	200
Eu-154	200

Assuming that all activity present was due to the isotope with the smallest Category 3 Threshold (200 Ci Ag-108m, Eu-154), the total dispersible activity would equal less than one-tenth of the 1% of the Category 3 threshold (0.1953/200). This represents a maximal potential dose of less than 10 mRem effective whole body where exposure is calculated at 30 meters for one day of inhalation and direct exposure, while the ingestion pathway is determined over a longer exposure (as per DOE-STD-1027-92, Attachment 1).

To approach the dose consequences of Risk Assessments No. 001 and 002 would require dust inventories 500 times higher.

The potential consequences discussed here most closely correspond to the definition of Hazard Severity III - **MARGINAL** (per Table 3.2, Hazard Severity), primarily due to the potential for minor personnel injury.

Risk Category (as defined by Table 3.4)

Both the pre-mitigation combination of Severity = **MARGINAL** with Probability = **EXTREMELY REMOTE**, and the post-mitigation combination of Severity = **MARGINAL** with Probability = **IMPOSSIBLE**, define the risk category as **ROUTINE** for the operations under this ASA.

3.2.5 Risk Assessment No. 004 covering Loss of Pile Negative-Pressure Ventilation

SYSTEM: BGRR Facility **NUMBER:** 004
HAZARD: To On-site Personnel

Event:	Loss of Pile's Negative Pressure Ventilation
Possible Consequences & Hazards:	Contamination of building's housing facility and internal structures / equipment. Radiation exposure to on-site personnel. Release of radioactive materials/ radiation to the environment. Exposure to radioactive materials through ingestion, inhalation, and dermal exposure.
Potential Initiators:	Failure of fan or loss of power.

Risk Assessment Prior to Mitigation						
Severity:	I ( ) Catastrophic	II ( ) Critical	III ( ) Marginal	IV (X) Negligible		
Probability:	A ( ) Frequent	B (X) Probable	C ( ) Occasional	D ( ) Remote	E ( ) Extr Remote	F ( ) Impossible
Risk Category:	1 ( ) High	2 ( ) Moderate	3 ( ) Low	4 (X) Routine		

Hazard Mitigation:	Limited radiological inventory at risk and available for release from entire facility (<Nuclear Hazard Category 3 Threshold), considering the activities covered by this ASA. Additional limitation on fraction of entire facility's inventory available as a result of the physical forms and distribution of inventory materials. Fan alarm indicating loss of negative pressure. Results from BNL's Committee Report on HVAC testing at the BGRR Complex [35]. Lack of significant activity found on replacing HEPA filters.

Risk Assessment Following Mitigation						
Severity:	I ( ) Catastrophic	II ( ) Critical	III ( ) Marginal	IV (X) Negligible		
Probability:	A ( ) Frequent	B ( ) Probable	C (X) Occasional	D ( ) Remote	E ( ) Extr Remote	F ( ) Impossible
Risk Category:	1 ( ) High	2 ( ) Moderate	3 () Low	4 (X) Routine		

Description - Loss of Pile Negative-Pressure

Hazard Probability (as defined in Table 3.3)

After the BGRR was taken out of operation in 1969, the HVAC system was modified to keep the reactor at a negative pressure relative to Building 701, to ensure there was no potential for airborne transport of the residual radioactivity in Building 702 (Bioshield and Graphite Pile) into Building 701. This was done because Building 701 was being converted into the BNL Science Museum, which was to be open to the public, including primary-school children.

Exhaust ducts were isolated from the stack by closing the valves at the discharge of the primary- and secondary-air fans to prevent reverse flow through them. Plywood covers were installed over the west- and east-air inlet ducts, separating the ducts from the intake bays and louvers. A small auxiliary fan and HEPA filter was installed in the east-intake bay, which drew suction from the Pile via a hole in the plywood cover separating the east-inlet duct from the east air-intake bay; it exhausted into the isolated east-intake bay. This reversed the flow through the east air-inlet duct (adapted from "BNL Committee Report on HVAC Testing at the BGRR Complex," December 1998 [35]).

During the approximately 20 years that the Science Museum was housed in Building 701, the Pile Negative-Pressure System shut down a number of times, including shutdowns for maintenance and accidental ones caused by power outages or equipment failures.

For these reasons, the unmitigated probability conservatively assigned to Loss of Pile Negative-Pressure Ventilation was **PROBABLE** (likely to occur several times in life cycle of the system).

Considering the mitigation factors listed under Risk Assessment No. 004, and the limited life-cycle remaining, post-mitigation probability is reduced to **OCCASIONAL** (likely to occur sometime in life-cycle of the system).

Hazard Severity (as defined by Table 3.2)

The event addressed under this Risk Assessment occurred several times during the history of the facility without any detected spread of airborne radioactivity or contamination from Building 702 to 701.

Since the BGRR was defueled and shut down approximately 30 years ago (and the Science Museum relocated about 2 years ago to another building not part of the BGRR Complex), there are no programmatic delays or repair costs associated with minor damage caused by Loss of Pile Negative Pressure Ventilation. Since personnel are not assigned to the BGRR Complex, other than a few temporary decommissioning staff located in office space in Building 701, the potential is small for occupational illness or injury resulting from Loss of Pile Negative-Pressure Ventilation.

The limited activated/contaminated dust inventory available for airborne transfer from Building 702 to 701 (as defined in Risk Assessment No. 003 - Graphite Dust Detonation) was conservatively bounded at less than one-tenth of 1% of the Hazard Category 3 Threshold. This represents a maximal potential dose of less than 10 mRem effective whole body where exposure is calculated per DOE-STD-1027-92, Attachment 1.

The potential consequences discussed here most closely correspond to the definition of Hazard Severity IV - **NEGLIGIBLE** (per Table 3.2, Hazard Severity).

Risk Category (as defined by Table 3.4)

Both the pre-mitigation combination of Severity = **NEGLIGIBLE** with Probability = **PROBABLE,** and the post-mitigation combination of Severity = **NEGLIGIBLE** with Probability = **OCCASIONAL**, result in the Risk Category being defined as **ROUTINE** for the activities under this ASA.

3.2.6 Risk Assessment No. 005 covering Loss of Pile Negative-Pressure Filtration

SYSTEM: BGRR Facility **NUMBER:** 005
HAZARD: To On-site Personnel

Event:	Loss of Pile's Negative-Pressure Filtration
Possible Consequences & Hazards:	Radiation exposure to on-site personnel. Release of radioactive materials/radiation to the environment. Exposure to radioactive materials through ingestion, inhalation, or dermal exposure.
Potential Initiators:	Failure of, or fire in, the filter.

Risk Assessment Prior to Mitigation						
Severity:	I ( ) Catastrophic	II () Critical	III ( ) Marginal	IV (X) Negligible		
Probability:	A ( ) Frequent	B (X) Probable	C ( ) Occasional	D ( ) Remote	E ( ) Extr Remote	F ( ) Impossible
Risk Category:	1 ( ) High	2 ( ) Moderate	3 ( ) Low	4 (X) Routine		

Hazard Mitigation:	Limited radiological inventory at risk and available for release from entire facility (<Nuclear Hazard Category 3 Threshold), in consideration of the activities covered by this ASA. Additional limitation on fraction of entire facility's inventory available as a result of the physical forms and distribution of inventory materials. CAM instrumentation. Analysis by BNL's Committee Report on HVAC testing at the BGRR Complex [35] Lack of significant activity found on replacing HEPA filters.

Risk Assessment Following Mitigation						
Severity:	I ( ) Catastrophic	II ( ) Critical	III ( ) Marginal	IV (X) Negligible		
Probability:	A ( ) Frequent	B ( ) Probable	C (X) Occasional	D ( ) Remote	E ( ) Extr Remote	F ( ) Impossible
Risk Category	1 ( ) High	2 ( ) Moderate	3 ( ) Low	4 (X) Routine		

Description - Loss of Pile Negative-Pressure Filtration

Hazard Probability (as defined in Table 3.3)

After taking the BGRR out of operation in 1969, the HVAC system was modified to keep the reactor at a negative pressure relative to Building 701, to ensure that no residual radioactivity in Building 702 (Bioshield and Graphite Pile) could be transported by air into Building 701 or to the environment. This was done because Building 701 was being converted into the BNL Science Museum, open to the public, including primary school children.

Exhaust ducts were isolated from the stack by closing the valves at the discharge of the primary- and secondary-air fans to prevent reverse flow through them. Plywood covers were installed over the west and east air-inlet ducts, separating them from the intake bays and louvers. A small auxiliary fan and HEPA filter was installed in the east-intake bay, which drew suction from the Pile via a hole in the plywood cover separating the east-inlet duct from the east air-intake bay and exhausted into the isolated east intake bay. This reversed flow through the east air inlet duct (adapted from "BNL Committee Report on HVAC Testing at the BGRR Complex," December 1998 [35]).

During the approximately 20 years that the Science Museum was housed in Building 701, the Pile Negative-Pressure System shut down several times, including shutdowns for maintenance and accidental ones caused by power outages or equipment failures, though never due to failures of the HEPA filter.

For these reasons, the unmitigated probability conservatively assigned to Loss of Pile Negative-Pressure Filtration was **PROBABLE** (likely to occur several times in life-cycle of the system).

Accounting for the mitigation factors listed under Risk Assessment No. 005, and the limited life-cycle remaining, post-mitigation probability is reduced to **OCCASIONAL** (likely to occur sometime in life cycle of system).

Hazard Severity (as defined by Table 3.2)

While the Pile Negative-Pressure Ventilation system failed several times during the history of the facility without any detected spread of airborne radioactivity or contamination from Building 702 to 701, the HEPA filters have never failed. When they are routinely replaced for preventive maintenance, no radioactive graphite-dust loading is detected.

Since the BGRR was defueled and shut down approximately 30 years ago (and the Science Museum relocated 2 years ago to another building not part of the BGRR Complex), there are no programmatic delays or repair costs associated with minor damage caused by Loss of Pile Negative-Pressure Filtration. No personnel are assigned to the BGRR Complex, other than the few temporary decommissioning staff occupying office space in Building 701, so there is a small potential for occupational illness or injury resulting from Loss of Pile Negative-Pressure Filtration.

The limited activated/contaminated dust inventory available for airborne transfer from Building 702 to 701 or to the environment (as defined in Risk Assessment No. 003 - Graphite Dust Detonation) was conservatively bounded at less than one-tenth of 1% of the Hazard Category 3 Threshold. This represents a maximal potential dose of less than 10 mRem effective-whole-body-dose where exposure is calculated per DOE-STD-1027-92, Attachment 1.

The potential consequences discussed here most closely correspond to the definition of Hazard Severity IV - **NEGLIGIBLE** (per Table 3.2, Hazard Severity).

Risk Category (as defined by Table 3.4)

Both the pre-mitigation combination of Severity = **NEGLIGIBLE** with Probability = **PROBABLE**, and the post-mitigation combination of Severity = **NEGLIGIBLE** with Probability = **OCCASIONAL**, define the Risk Category as **ROUTINE** for the work planned under this ASA.

3.2.7 Risk Assessment No. 006 Covering Crane Load Drop

SYSTEM: BGRR Facility **NUMBER:** 006
HAZARD: To On-site Personnel, Equipment

Event:	Crane-Load Drop
Possible Consequences & Hazards:	Radiation exposure to on-site personnel. Release of radioactive materials/ radiation to the building and/or environment. Exposure to radioactive materials through ingestion, inhalation, and/or dermal exposure. Contamination of building or room.
Potential Initiators:	Equipment failure, power loss, operator's error, failure of handling equipment.

Risk Assessment Prior to Mitigation

Severity:	I ( ) Catastrophic	II ( ) Critical	III ( ) Marginal	IV (X) Negligible		
Probability:	A ( ) Frequent	B ( ) Probable	C (X) Occasional	D ( ) Remote	E ( ) Extr Remote	F ( ) Impossible
Risk Category:	1 ( ) High	2 () Moderate	3 ( ) Low	4 (X) Routine		

Hazard Mitigation:	Limited radiological inventory at risk and available for release from entire facility (<Nuclear Hazard Category 3 Threshold), in view of the activities covered by this ASA. Additional limitation on fraction of entire facility's inventory available as a result of the physical forms and distribution of the inventory materials, and the strength of the Bioshield. Inspection and maintenance of cranes and qualification of operators before using them. Building structure's design criteria in compliance with AEC's requirements (including main floor design loading of 500 lbs/sq ft; intermediate upper floor design loading of 125 lbs/sq ft; concrete slabs at base of each window bay design loading of 300 lbs/sq ft; and experimental balconies design loading of 1,000 lbs/sq ft).

Risk Assessment Following Mitigation

Severity:	I ( ) Catastrophic	II ( ) Critical	III ( ) Marginal	IV (X) Negligible		
Probability:	A ( ) Frequent	B ( ) Probable	C ( ) Occasional	D (X) Remote	E ( ) Extr Remote	F ( ) Impossible
Risk Category:	1 ( ) High	2 ( ) Moderate	3 () Low	4 (X) Routine		

Description - Crane Load Drop

Hazard Probability (as defined in Table 3.3)

The largest crane in the BGRR Complex is the 10-Ton Overhead Crane in Building 701. While routine surveillance and maintenance of the building was undertaken regularly, even after the BGRR was shut down and defueled, more stringent inspection and testing was completed in preparation for possibly using the crane during the BGRR Decommissioning Project.

Though the crane will only be operated by dedicated, qualified crane-operators from the Riggers' Shop of the Plant Engineering Division, it was conservatively assumed that the unmitigated probability of a Crane Load Drop was **OCCASIONAL** (likely to occur sometime in the life-cycle of system).

Considering the mitigation factors listed on Risk Assessment No. 006, as well as the limited life cycle remaining, post-mitigation probability is reduced to **REMOTE** (not likely to occur in life cycle of the system, but possible).

Hazard Severity (as defined by Table 3.2)

Since the BGRR was defueled and shut down approximately 30 years ago, there are negligible programmatic delays (< 4 days) or repair costs (< $50,000) associated with any damage caused by any crane load drop. No personnel are assigned to the BGRR Complex (other than the few temporary decommissioning staff now in office space in Building 701), so the potential for occupational illness or injury is small. This is especially true considering the expertise and qualifications of the crane operator(s) and assistants.

Any crane-load drop would be limited to only a fraction of the BOP radiological inventory (assuming a shielded waste-container was dropped). Impacts causing the need to consider the release of the Pile inventory are not credible based on the use of the 10-Ton Overhead Crane and the design-basis for the Bioshield's confinement of the graphite Pile. Using larger cranes inside Building 701 lifting loads heavier than 10 tons is outside the scope of this analysis, and would have to be analyzed separately under a USI (using BGRR-SOP-0902, "Safety Evaluations for Unreviewed Safety Issue Determinations").

Even assuming a limited BOP radiological inventory was available and at risk and could be released in a Crane Load Drop (a shielded waste-container), the material that could be released in the form of transferable contamination or contaminated dust is conservatively estimated at less than 15% of the BOP inventory (discussed) for Seismic Event-Risk Assessment No. 1. This represents a maximal potential dose of less than 5 rem effective-whole-body-dose where exposure is calculated in accordance with DOE-STD-1027-92, Attachment 1.

The potential consequences discussed here most closely correspond to the definition of Hazard Severity IV, **NEGLIGIBLE** (per Table 3.2, Hazard Severity).

Risk Category (as defined by Table 3.4)

Both the pre-mitigation combination of Severity = **NEGLIGIBLE** with Probability = **OCCASIONAL**, and the post-mitigation combination of Severity = **NEGLIGIBLE** with Probability = **REMOTE**, so that the Risk Category is defined as **ROUTINE**.

3.2.8 Risk Assessment No. 007 covering Fire

SYSTEM: BGRR Facility **NUMBER:** 007
HAZARD: To On-site Personnel, Equipment

Event:	Fire
Possible Consequences & Hazards:	Radiation exposure to on-site personnel. Release of radioactive materials/ radiation to the building and/or environment. Exposure to radioactive materials through ingestion, inhalation, and/or dermal exposure. Contamination of building or room. Program delays.
Potential Initiators:	Natural phenomenon, operator's error, failure of equipment.

Risk Assessment Prior to Mitigation

Severity	I ( ) Catastrophic	II ( ) Critical	III ( ) Marginal	IV (X) Negligible		
Probability	A ( ) Frequent	B ( ) Probable	C (X) Occasional	D ( ) Remote	E ( ) Extr Remote	F ( ) Impossible
Risk Category	1 ( ) High	2 ( ) Moderate	3 ( ) Low	4 (X) Routine		

Hazard Mitigation:	Limited radiological inventory at risk and available for release from entire facility (<Nuclear Hazard Category 3 Threshold), in consideration of the activities covered by this ASA. Additional limitation on fraction of entire facility's inventory available as a result of the physical forms and distribution of inventory materials. Limitations on inventory of combustible materials stored within the facility and restrictions on introducing new combustible material. Enhanced stabilization of Reactor Pile including, but not limited to, isolation of Building 702 and reduction of air in-leakage. Replacement of plywood covers on east and west air inlet ducts with metal or otherwise fireproofed material. Fire detection/alarm systems under regular program of surveillance and maintenance. Regular change of replaceable HEPA filters. Building protected against lightning by proximity of Reactor stack.

Risk Assessment Following Mitigation

Severity:	I ( ) Catastrophic	II ( ) Critical	III ( ) Marginal	IV (X) Negligible		
Probability:	A ( ) Frequent	B ( ) Probable	C ( ) Occasional	D (X) Remote	E ( ) Extr Remote	F ( ) Impossible
Risk Category:	1 ( ) High	2 ( ) Moderate	3 ( ) Low	4 (X) Routine		

Description - Fire

Hazard Probability (as defined in Table 3.3)

Risk Assessment No. 003 covering Graphite Dust Detonation already provides information on the difficulties associated with trying to ignite graphite, even in the form of dust. Further, according to "A Safety Assessment of the Use of Graphite in Nuclear Reactors Licensed by the NRC," NUREG/CR-4981 [32], the following are the bounding conditions needed to initiate burning of graphite:

- Graphite must be heated to at least 650°C.
- This temperature must be maintained either by the heat of combustion or some outside energy source.
- There must be an adequate supply of oxidant (air or oxygen).
- The gaseous source of oxidant must flow at a rate that can remove gaseous reaction products without excessively cooling the graphite surface.

Although there is little exposed combustible-loading within the BGRR Complex (especially since the museum debris was removed), and automated fire-detection and alarm systems (although not automated fire-suppression) are present in the facility, the unmitigated probability conservatively assigned to Fire was **OCCASIONAL** (likely to occur sometime in life-cycle of system).

Considering the mitigation factors listed on Risk Assessment No. 007, and the limited life-cycle remaining, post-mitigation probability is reduced to **REMOTE** (not likely to occur in life cycle of system, but possible).

Hazard Severity (as defined by Table 3.2)

Since the BGRR was shut down and defueled approximately 30 years ago, there are no programmatic delays or repair costs associated with any anticipated fire damage. No one is assigned to the BGRR Complex, other than a few temporary decommissioning staff occupying office space in Building 701, so the potential for occupational illness or injury is small.

Because of the lack of credible ignition scenarios for the graphite Pile, and the great difficulty in keeping a fire burning even if one were ignited, the radiological impact of the fire will be assessed using the BOP radiological inventory.

As discussed under Risk Assessment No. 001 covering Seismic Event, any such accident could realistically involve only a small fraction of the entire BOP radiological inventory. Similarly, a fire at the BGRR Complex cannot involve the entire BOP radiological inventory, due to the form and distribution of the activity (widely dispersed low-level contamination on non-combustible surfaces).

Assuming limited BOP radiological material were available and at risk to be burnt and released in a fire, this inventory is estimated at less than 15% of the BOP inventory. That amount would create a maximal potential dose of less than 5 rem effective-whole-body-dose where exposure is calculated in accordance with DOE-STD-1027-92, Attachment 1.

The potential consequences discussed most closely correspond to the definition of Hazard Severity IV, **NEGLIGIBLE** (per Table 3.2, Hazard Severity).

Risk Category (as defined by Table 3.4)

Both the pre-mitigation combination of Severity = **NEGLIGIBLE** with Probability = **OCCASIONAL**, and the post-mitigation combination of Severity = **NEGLIGIBLE** with Probability = **REMOTE**, result in the Risk Category being defined as **ROUTINE** for the work contemplated under this ASA.

3.2.9 Risk Assessment No. 008 covering Facility-Workers' Exposure to Toxic/Hazardous Materials

SYSTEM: BGRR Facility **NUMBER:** 008
HAZARD: To On-site Personnel, Equipment

Event:	Facility-Workers' Exposure to Toxic/Hazardous Material
Possible Consequences & Hazards:	Toxic exposure to on-site personnel. Release of toxic/hazardous materials to the building and/or environment. Exposure to toxic/hazardous materials through ingestion, inhalation, and/or dermal exposure. Contamination of building or room. Program delays
Potential Initiators:	Natural phenomena, operators' error, or failure of equipment breaching the deactivated piping or equipment containing residual hazardous/toxic material.

Risk Assessment Prior to Mitigation						
Severity:	I ( ) Catastrophic	II ( ) Critical	III ( ) Marginal	IV (X) Negligible		
Probability:	A ( ) Frequent	B ( ) Probable	C (X) Occasional	D ( ) Remote	E ( ) Extr Remote	F ( ) Impossible
Risk Category:	1 ( ) High	2 () Moderate	3 ( ) Low	4 (X) Routine		

Hazard Mitigation:	Limited hazardous/toxic inventory available for release from entire facility (no significant inventories of non-radiological hazardous material identified during PHA). Limitations on the inventory of combustible materials stored within the facility and restrictions on introducing new combustible material. Limitations on introducing new hazardous/toxic material to the facility during the remaining life of project. Work controls mandating the use of PPE during hazardous-entry operations.

Risk Assessment Following Mitigation						
Severity:	I ( )Catastrophic	II ( ) Critical	III ( ) Marginal	IV (X) Negligible		
Probability:	A ( ) Frequent	B ( ) Probable	C ( ) Occasional	D (X) Remote	E ( ) Extr Remote	F ( ) Impossible
Risk Category:	1 ( ) High	2 ( ) Moderate	3 () Low	4 (X) Routine		

Description - Facility-Workers' Exposure to Toxic/Hazardous Materials

Hazard Probability (as defined in Table 3.3)

Because there are no significant inventories of non-radiological hazardous materials within the BGRR Complex, this accident scenario was not developed as part of the original draft of BGRR Hazards Summary and Recommendations Document, nor in the draft BGRR-DBIO (which evolved into this ASA document). However, during the most recent reviews and comments, it was suggested that this accident scenario should be added because it was present in the Safety Authorization Bases of other old reactor-decommissioning projects.

Among the non-radiological hazardous materials to be found within the BGRR Complex are the following:

- asbestos and/or asbestos-containing material (ACM)
- mercury
- lead shielding and/or lead-based paint
- PCBs
- cadmium

Despite the absence of significant quantities of non-radiological hazardous materials and the existence of a well-developed Industrial Hygiene and Work Planning/Control Program, the unmitigated probability conservatively assigned to Facility Workers' Exposure to Toxic/Hazardous Materials was **OCCASIONAL** (likely to occur sometime in life-cycle of system).

Taking into account the mitigation factors listed on Risk Assessment No. 008, and the limited life-cycle remaining, post-mitigation probability is reduced to **REMOTE** (not likely to occur in life cycle of system, but possible).

Hazard Severity (as defined by Table 3.2)

Since the BGRR was shut down and defueled approximately 30 years ago, there are no programmatic delays or repair costs associated with any anticipated damage caused by Facility Workers' Exposure to Toxic/Hazardous Materials.

By definition, this event has no radiological impact.

Based on the extremely limited inventories of non-radiological hazardous materials known to exist within the BGRR Complex and the extensive Industrial Hygiene/Work Controls Program in effect for facility workers on the BGRR Decommissioning Project, any potential accidental exposure should not result in any lost time, injury, or occupational illness.

The potential consequences discussed here most closely correspond to the definition of Hazard Severity IV, **NEGLIGIBLE** (per Table 3.2, Hazard Severity).

Risk Category (as defined by Table 3.4)

Both the pre-mitigation combination of Severity = **NEGLIGIBLE** with Probability = **OCCASIONAL** and the post-mitigation combination of Severity = **NEGLIGIBLE** with Probability = **REMOTE**, result in the Risk Category being defined as **ROUTINE** for the activities contemplated under this ASA.

3.3 Dose Assessment Summary

The analyses performed in Section 3.2.2 qualitatively defined logically, but conservatively, that up to 15% of the BOP inventory described in Section 2.3 could possibly be released in a near incredible accident at the BGRR. This represents the worst-case radiological dose for the eight accidents analyzed in Section 3.2. In order to convert 15% BOP to an estimated dose, the following logic/thought process was applied:

BOP Inventory for Table 2.3	up to 300% of Haz Cat 3 Threshold
Estimated % Releasable from Analysis	15% of the BOP Inventory
Therefore, % of TQ Releasable	≅45% of Haz Cat 3 Threshold

The basis of 100% of the Haz Cat 3 TQ [4] values is 10 Rem to the maximum exposed individual, at 30 meters away from the release, over a 24-hour period due to direct exposure, inhalation, and longer term ingestion exposure.

Therefore, the worst-case exposure was estimated at:

$$45\% \text{ of } 10 \text{ Rem} = 4.5 \text{ Rem in 24 hours at 30 meters } (< 5 \text{ Rem})$$

3.4 Final Hazards Classification

This section and Tables 3.5 and 3.6 summarize the Risk Assessment for the BGRR given in Section 3.2. Eight types of events are addressed under the Risk Assessment for the BGRR in this ASA for the activities covered:

- 001 Seismic Event
- 002 High Winds
- 003 Graphite Dust Detonation
- 004 Loss of Pile Negative-Pressure System Ventilation
- 005 Loss of Pile Negative-Pressure System Filtration
- 006 Crane Load Drop

- 007 Fire
- 008 Facility Workers' Exposure to Toxic Material

These are discussed in detail as part of the Hazards Analysis in Section 3.2. These failure modes represent the known or anticipated types possible for the current BGRR Facility. The specific examples represent the most severe combination of consequences and frequency deemed credible. Thus, each separate Risk Assessment Table represents an individual envelope encompassing a variety of similar or related events whose severity and probability fall within the bounds of the specific event. Each such event includes all lesser similar ones with lower overall risk (a product of the functions of severity or consequence, and probability or frequency). This combination of assorted types of events caused by any of a variety of potential initiators defines a bounding spectrum of accidents. The spectrum can cover or subtend numerous specific but unnamed incidents under their overlapping umbrellas, so long as the specific event does not exceed the envelope for the type it represents.

As summarized in the tables below, with the administrative controls and mitigating factors considered, only routine industrial risks are associated with the BGRR Decommissioning Project scope described in this ASA.

Table 3.5

PRE-MITIGATION RISK CATEGORIES

No.	Event	Hazard Severity[1]	Hazard Frequency[1]	Risk[2]
001	0.15g Seismic Event	Negligible	Remote	Routine
002	High Winds	Negligible	Occasional	Routine
003	Graphite-Dust Detonation	Marginal	Extremely Remote	Routine
004	Loss of Pile Negative-Pressure System Ventilation	Negligible	Probable	Routine
005	Loss of Pile Negative-Pressure System Filtration	Negligible	Probable	Routine
006	Crane Load Drop	Negligible	Occasional	Routine
007	Fire	Negligible	Occasional	Routine
008	Facility Workers' Exposure to Toxic/Hazardous Material	Negligible	Occasional	Routine

1. Severity and frequency are discussed in Section 3.2.
2. Risk (based on severity and frequency) is defined in Table 3.4.

Table 3.6

POST-MITIGATION RISK CATEGORIES				
No.	**Event**	**Hazard Severity**[1]	**Hazard Frequency**[1]	**Risk**[2]
001	0.15g Seismic Event	Negligible	Extremely Remote	Routine
002	High Winds	Negligible	Remote	Routine
003	Graphite-Dust Detonation	Marginal	Impossible	Routine
004	Loss of Pile Negative-Pressure System Ventilation	Negligible	Occasional	Routine
005	Loss of Pile Negative-Pressure System Filtration	Negligible	Occasional	Routine
006	Crane Load Drop	Negligible	Remote	Routine
007	Fire	Negligible	Remote	Routine
008	Facility Workers' Exposure to Toxic/Hazardous Material	Negligible	Remote	Routine

1. Severity and frequency are discussed in Section 3.2.
2. Risk (based on severity and frequency) is defined in Table 3.4.

The Risk Assessment concludes that all events with or without mitigation present only a Routine Risk. This analysis did not postulate any accidents or natural phenomena that could result in a credible release mechanism for any of the radiological inventories discussed Section 2.3. Therefore, it is the conclusion of this analysis that there is no material at risk for potential release at the BGRR given the scope of work discussed in Section 1.4.

Using the methodology described in DOE's *Hazard Baseline Documentation* (and in Figure 1 therein) [5], the following logic is used to determine a **RADIOLOGICAL** classification for the BGRR:

- Preliminary Hazards Classification – Nuclear Category 2 described in Section 3.1 The "Potential Releasable Radiation Meets or Exceeds DOE-STD-1027, Attachment 1 Thresholds" – No - There is no material at risk of potential release based on the risk assessment of all postulated accidents or natural phenomena presented in Section 3.3 in accordance with BNL's ES&H STD 1.3.3.

- Potential Releasable Radiation RQ Meets or Exceeds 40CFR302, Appendix B Levels- Assuming a maximal potential release of up to15% of the BOP inventory defined under Section 2.3, the answer is YES.

- Potential Releasable Hazardous Material Below 29CFR1910.119 or 40CFR355 Thresholds - this analysis was not done because definitive inventory numbers were lacking, therefore, a YES answer (threshold is exceeded) is conservatively assumed.

Therefore **RADIOLOGICAL** is the correct classification for the BGRR.

4.0 CONTROLS AND COMMITMENTS

This section discusses the safety controls and commitments applicable to the BGRR Decommissioning Project's work.

Overlaying all the Project's operations are BNL's work-process controls and procedures for all activities (see Appendix A).

4.1 Special Controls

To ensure that the conditions assumed in the hazard analysis are maintained, the administrative controls defined in Section 1.3 will be strictly adhered to.

4.2 Project-Specific Controls

4.2.1 Safety-Significant Structures, Systems, and Components

The scope of work defined in this ASA does not employ safety-significant structures, systems, or components. This is based on the evaluations in Section 3.2 which show that the unmitigated consequences of credible events remain below the level of significance defined in DOE-STD-3009-94, *Preparation Guide for U.S. DOE Non-Reactor Nuclear Facility Safety Analysis Reports*, that is, death or multiple serious injury.

4.3 Programmatic Controls

4.3.1 Conduct of Operations

Conduct of operations is imposed to ensure that work is performed in a controlled, organized manner, that all facets of the work have been considered, and that necessary documentation is maintained.

Field activities and decontamination and decommissioning (D&D) projects are governed by the Project's plan, applicable field-support instructions, and specific work-instructions. The Project's plan is based on a graded approach to the Conduct of Operations authorized by DOE's Order 5480.19 [36]. It applies to all BGRR Project personnel, assigned or matrixed, who work under the responsibility and direction of the BGRR's Project Manager.

Conduct of Operations strongly emphasizes technical competency, workplace discipline, and personal accountability to ensure a high level of performance. Project personnel are responsible for fully complying with the Project's plan, and, if it conflicts with other instructions or directions, work shall be safely stopped until the problem is resolved.

Safety is the first priority, and all planning shall include appropriate safety analyses to identify potential safety- and health-risks and the means to mitigate them. Workers shall not start work until approved safety procedures, instructions, and directions are provided for non-routine operations.

Conduct of Operations requires workers to be alert and aware of conditions affecting the job site. Workers in the field should be notified of changes in the status of the facility and work areas, abnormalities, and any difficulties encountered in carrying out operations. Similarly, workers shall notify the chain-of-command of any unexpected situations. In accordance with the severity of a finding (i.e., emergency condition), notification requirements will be expanded to include upper-tier management and regulatory agencies.

4.3.2 Project Controls

Project controls will be established using existing programs and procedures, and accepted practices will be supplemented by specific programs, procedures, work instructions, and quality procedures necessary to acquire, analyze, and report defensible Project information for the BGRR. This will include controls for obtaining Project information, sampling and analysis plans, quality-control requirements, quality assurance, and health and safety plans.

Project activities and discrete work packages to be performed will be compared with the scope of the approved BGRR ASA. Where warranted, BGRR-SOP-0902, "Safety Evaluations for Unreviewed Safety Issue Determinations," [7] will be used to evaluate any activity and work package, and provide a safety analysis for DOE's review and approval.

The project will be controlled using a top-down approach. The BGRR Project Management Plan and the BGRR Quality Assurance Project Plan (QAPP) [37] are the program documents that will control the work. Procedures, training, surveys, evaluations, and analyses will be performed using documents or procedures that have sufficient guidance to meet the program's requirements.

The primary method for controlling the Project to ensure consistent, reproducible results is by using approved procedures. The Project will use work-control procedures to establish safe work conditions by using work permits, radiation-work permits, confined space, and cutting- and burning-permits.

Section 1.3, Hazard Classification Summary, has the five Administrative Controls governing the overall special project.

4.3.3 Radiological Controls

Standard BNL controls, based on 10CFR835 [38], for work in radiological areas were assessed as adequate to control these activities. They provide for the following: Radiation Work Permits (RWPs) that identify the specific conditions and govern the specific requirements for an activity; periodic radiation- and contamination-surveys of the work area; and, periodic or continuous observation of the work by radiological control technicians. In addition, ALARA (As Low as Reasonably Achievable) planning will be developed in accordance with BNL's procedures for all work packages. It will identify the requirements for shielding, contamination control (including local-ventilation controls), radiation monitoring, and other radiation control for individual tasks conducted during the BGRR Decommissioning Project's plan.

4.3.4 Occupational Safety Controls

Workers' safety and health considerations, comparable to, or exceeding, the levels required by the Occupational Safety and Health Act (OSHA) [39] will be integrated into the BGRR Decommissioning Project (and subsequent BGRR-related work) during work planning. The workers' involvement in the levels of safety analysis required for the various BGRR tasks and the planning will follow the guidance in BNL's ES&H Standard 1.3.6, "Work Planning and Control System" and DOE Policy 450.4, "Integrated Safety Management System," (ISMS) to ensure that all elements of work are useful, efficient, safe, and satisfactory to all concerned. DOE's guidance will be used as far as practicable [40-44].

4.3.5 Health and Safety Plan

All work covered under this ASA will be conducted in accordance with the BGRR's overall Health and Safety Plan and approved health and safety plan procedures (described in BNL's ES&H Standards Manual). Additionally, work-package-specific health and safety planning documents will be developed, where needed, for the risks associated with the work. Health Physics support will be present, as necessary, during drilling and sampling. The ALARA concept will be followed during all phases of field work. A detailed work-package will be prepared for each major task and removal action as defined in the Project's plan, to document the approved activities and the controls necessary to mitigate any hazard encountered. It is recognized that certain BGRR structures and systems have the potential for producing very high levels of radiation exposure and releasing radioactive contamination when boundaries are breached. Therefore, each work package will be reviewed and approved to assure appropriate work controls were incorporated to protect workers, the facility, the environment, and the public [45].

As necessary, technical and professional personnel will be OSHA-trained following 29 CFR, Part 1910.120. In addition, all personnel will have the appropriate BNL Radiation

Control Training. BGRR facility training also will be completed by all personnel working within the facility, and training will include, as a minimum, the following:

- Radiological/hazardous material handling techniques
- Quality-assurance requirements for site Project work
- Recognition, control, and mitigation requirements for radiological-, chemical-, and physical-hazards that may be present

4.3.6 Training

BNL provides continuing training for its HP personnel and other workers who may be exposed to radioactive materials. The training varies according to potential exposure and the employee's job duties, but all personnel will receive Emergency Awareness Training and Stop Work Training. Routine and standard training for radiological work will consist of DOE's standardized core radiological worker courses, administered in accordance with BNL's Radiological Controls Manual [46]. Employees who will be involved in measuring and sampling will have additional training on characterizing equipment, special sampling and measurement techniques, and survey practices. A Project training matrix will be generated for all members of the BGRR Decommissioning Project, and they will participate in in-house training reviewing specific radiation-protection items, removal-action procedures, and quality assurance work specific to each planned major task. Documentation of training and participation in work briefings will be retained as part of the BGRR Decommissioning Project's records.

4.3.7 Stop Work

Established Stop Work processes and procedures ensure that all workers are trained and qualified to stop work (their own or others they may see) when the following occurs:

- there is an imminent danger to personnel, equipment, or the environment and immediate action is required, or
- radiological work is being performed in violation of established site/DOE radiological-control requirements, or has the potential to result in significant radiological exposure or releases of radioactive material.

4.3.8 Occurrence Reporting

The Occurrence Reporting System, defined by BNL ES&H Manual Standard 1.1.0, "Occurrence Reporting System," Rev. 5, dated March 1, 1997, and as committed to and implemented by the BGRR Decommissioning Project, requires that occurrences (including problems, concerns, and adverse events or conditions) are promptly reported to DOE and other appropriate organizations both external and internal, where those occurrences could

- affect the health and safety of the public,
- have a noticeable adverse effect on the environment,
- endanger the health and safety of employees and other workers,
- seriously impact the operations and intended purpose of BNL's facilities,
- result in loss or damage of property, and
- adversely affect national security or the security interest of DOE or BNL.

In addition to reporting such events, the standard mandates that the appropriate corrective actions(s) are determined, and are taken.

4.3.9 Quality Assurance

The BGRR Decommissioning Project Quality Program and Plans incorporate a graded approach to implement DOE Order 414.1, "Quality Assurance," issued 11/24/98 (previously 5700.6C). In general, the following quality elements are established:

- management responsibilities and quality system
- personnel training and qualification,
- quality improvement system,
- document- and record-control,
- work-process, item, and equipment control,
- design-process control,
- procurement,
- inspection and acceptance testing,
- management assessments, and
- independent assessments.

The BGRR Decommissioning Project also maintains a Self-Assessment Plan and program that is closely tied to, but not solely composed of, the management assessments and independent assessments.

4.3.10 Fire Protection

Manual fire protection shall be provided by the BNL Fire Department throughout the BGRR Decommissioning Project. Fire-detection systems shall provide the level of protection required during the BGRR Decommissioning Project work, in accordance with BNL's ES&H Manual Standard 4.0.0, "Fire Safety Program." The requirements of NFPA 241, "Standard for Safeguarding Construction, Alteration, and Demolition Operations," [47] shall be met for all activities. No flammable gases will be stored inside BGRR

Complex buildings; only those gases connected for use will be there. Any temporary disconnections of fire-protection system equipment to support decommissioning shall be made in compliance with BNL's ES&H Manual Standard 4.2.0, "Impairment of Fire Protection Systems and Fire Alarm Systems," Rev. 1, January 28, 1998.

4.3.11 Emergency Response

BNL's Emergency Plan describes the organization, facilities, and procedures which would be used to protect Laboratory employees, the general public, emergency workers, and the environment in the unlikely event of an Operational Emergency anywhere within the Laboratory. The plan implements and complies with applicable DOE Orders and Federal regulations.

The BGRR Decommissioning Project's personnel are not members of BNL's Emergency Response Organization, nor have any special emergency-responder functions.

In accordance with BNL's ES&H Manual Standard 1.17.0, "Local Emergency Plans," Rev. 0, dated 1/8/98, the BGRR Local Emergency Plan describes the actions to be taken by Project personnel present whenever any emergency occurs at BNL, including potential emergencies at the BGRR Complex.

4.4 Commitments

4.4.1 Authorized Work Scope

Only the scope of work defined by this ASA will be executed under it. See Section 4.4.4, USI Procedure, for conducting work potentially outside the scope of this ASA on the BGRR Decommissioning Project.

4.4.2 Compliance with Special Controls

All special controls, e.g., Lockouts/Tagouts (LO/TOs), RWPs, Fire Protection Impairment Tags, Cutting (Welding Permits) shall be employed and followed where required.

4.4.3 Characterization and Hazards Analysis

The results of Radiological/Hazardous Material Characterization for ES&H and Waste Management shall be reviewed and factored into the USID/SE performed for any activity not totally covered by the ASA.

4.4.4 USI Procedure

In accordance with Section 1.4, Work Scope, and Section 1.5, Unreviewed Safety Issue (USI) Process, BGRR-SOP-0902, "Safety Evaluations for Unreviewed Safety Issues Determinations," shall be used whenever called for by Table 1.1, ASA Applicability Table, or whenever a question arises about the coverage by the ASA of the work to be performed.

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6.0 GLOSSARY

Activity: Sometimes used for *radioactivity*, particularly when referring to an amount of radioactivity (i.e., the number of nuclear transformations occurring in a given quantity of material per unit of time).

Airborne radioactivity: Radioactive particulates, mists, fumes, and gases in the air.

ALARA: A philosophy to maintain exposure to radiation As Low As Reasonable Achievable.

Alpha-bearing waste: Waste containing alpha-emitting radionuclides.

Alpha decay: Radioactive decay in which an alpha particle is emitted. This transformation lowers the atomic number of the nucleus by two and its mass number by four.

Alpha particles: The least penetrating but most energetic of radiation types. The particle is positively charged and relatively massive. Because of its size, it may easily be stopped in a few centimeters of air. Alpha-emitting wastes require no shielding. Alpha-emitting nuclides can be dangerous when ingested or inhaled because the particle's energy is transferred directly to adjacent cells.

Auditable Safety Analysis (ASA) - The Authorization Basis documentation for safety of a DOE facility below the threshold for Nuclear Hazard Category 3, also known as "Radiological Facility," per DOE-EM-STD-5502-04, "Hazard Baseline Documentation."

Background: The radiation dose received by everyone as a result of living on the Earth. Natural sources of radiation include cosmic rays (25% of total); terrestrial, including inside the body and in the environment (40% of total); and technological sources, including medical X-rays, fallout, nuclear facilities (35% of total).

Beta decay: Radioactive decay in which a beta particle is emitted.

Beta particles: These are charged particles (electrons or positrons) emitted from the decay of some radioactive elements and are more penetrating than alpha particles. Beta particles can penetrate skin and cause burns. They can travel several meters in air, but the principal hazard still comes from ingestion or inhalation of material that emits beta particles. Depending on the concentration, wastes containing material that emits beta particles may require some level of shielding. Beta particles can be stopped by a thick sheet (up to ½ inch) of plastic.

Biological shield: A mass of absorbing material placed around a reactor or radioactive source to reduce the radiation to a level that is safe for humans.

Characterization: An information-gathering process usually involving measurement or sampling and analysis of contaminants present.

Chemical hazards: Hazardous material (i.e., solids, liquids, or gases) with the potential for causing harm to people, the environment, or property.

Containment: A device used to prevent or minimize the spread of contamination, often a plastic enclosure with High Efficiency Particulate Air-filtered ventilation.

Contamination: Radioactive or hazardous material that has been deposited on the surfaces of structures or equipment or that has been mixed with another material.

Curie (Ci): The quantity of a radioactive material that has a disintegration rate of 3.7×10^{10} nuclear transformations per second.

Daughter product: A nuclide formed by the radioactive decay of another nuclide which, in this context, is called the *parent*.

Deactivation: The process of placing a facility in a safe and stable condition, including the removal of readily removable hazardous and radioactive materials to minimize the long-term cost of surveillance, and the implementation of maintenance programs that protect workers, the public, and the environment. Deactivation can include one-of-a-kind and first-of-a-kind tasks, such as removal of radioactive materials in ventilation duct work. It also includes routine surveillance and maintenance that are typically part of facility operation.

Decay, radioactive: A spontaneous nuclear transformation in which particles and/or gamma radiation is emitted.

Decommissioning: Takes place after deactivation and includes surveillance and maintenance, decontamination, or dismantlement. These actions are taken at the end of the life of a facility to retire it from service, with adequate regard for the health and safety of workers and the public and protection of the environment. The ultimate goal of decommissioning is unrestricted release or restricted use of the site. Surveillance and maintenance tasks during decommissioning are typically routine activities similar to those to any other life-cycle phase. A disposition project can also be in a long-term surveillance and maintenance (e.g., quiescent state) if no deactivation, decontamination, or dismantlement activities are conducted. This definition is not meant to imply that the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) is the controlling regulation for long-term surveillance and maintenance when decommissioning is not immediately undertaken.

Decontamination: The removal or reduction of residual radioactive and hazardous materials by mechanical, chemical, or other techniques to achieve a stated objective or condition. Decontamination may occur during all phases of facility disposition; however, the greatest decontamination activity usually occurs during decommissioning.

Decontamination agents: Those chemical materials used to effect decontamination.

Decontamination factor (DF): Defined as the original amount of radionuclide (A_o) divided by the final amount (A_f). In some cases, decontamination effectiveness is reported in terms of percent of contamination removed:

$$100\left[\frac{(A_o - A_f)}{A_o}\right] = 100\left(1 \frac{1}{DF}\right).$$

De minimus level: That level of contamination below which regulatory control is not required.

Disintegration, nuclear: Spontaneous nuclear transformation (radioactivity) characterized by the emission of energy and/or mass from the nucleus. The process is characterized by a definite half-life.

Disintegration rate: The rate at which disintegrations occur, characterized in units of time, e.g., disintegrations per minute (dpm).

Dismantlement: Those actions required to remove material, including radioactive or contaminated material, from the facility.

Disposal: The disposition of materials with the intent that the materials will not enter the environment in sufficient amounts to cause a health hazard.

Dose, occupational: The exposure of an individual to radiation imposed by employment.

Dose rate: The radiation dose delivered per unit time and measured, for instance, in rems per hour.

Entombment: The encasement of radioactive materials in concrete or other structural material sufficiently strong and structurally long-lived to ensure retention of the radioactivity until it has decayed to levels that permit restricted release of the site.

Exposure: The general result of occupying an area where radiation is incident on the body or where airborne radioactive or hazardous materials are inhaled. The unit for exposure to X-ray or gamma radiation is the Roentgen (R).

Facility: The physical complex of buildings and equipment within a site.

Facility disposition: Those activities that follow completion of program mission, including, but not limited to, surveillance and maintenance, deactivation, and decommissioning.

Facility hazard analysis: Analysis of identified hazards that arise within a facility and which may be encountered during its disposition. This includes the type, form, quantity, concentration, and locations of radioactive, chemically hazardous, and biological substances and materials within a facility; the hazardous substances' inherent harmful characteristics and conditions under which exposure may occur; and the physical hazards related to carrying out the work.

Fission: The splitting of a heavy nucleus into two or lighter nuclei (nuclides of lighter elements), accompanied by the release of a relatively large amount of energy and generally one or more neutrons. Fission can occur spontaneously, but usually it is caused by nuclear absorption of gamma rays, neutrons, or other particles.

Fission products: The lighter nuclides formed by the fission of heavy elements. The term also refers to the nuclides formed by the fission fragment's radioactive decay.

Gamma radiation: Electromagnetic radiation of extremely short wavelength similar to X-rays. Gamma radiation is highly penetrating. Therefore, gamma-emitting nuclides are a hazard both when ingested or inhaled and when exposure is external to the body. Heavy materials such as lead (or massive amounts of lighter materials) are effective protective shields.

Greenfield: Returning the footprint of the decommissioned facility to grass on top of clean soil.

Half-life, radioactive: The time in which half the atoms of a particular radioactive substance disintegrate to another nuclear form. Each radioactive isotope has a characteristic half-life, and measured half-lives vary from millionths of a second to billions of years.

Hazard: A chemical property, energy source, or physical condition that has the potential to cause illness, injury, death to personnel, or damage to property or the environment. This definition does not include the likelihood or credibility of potential accidents or the mitigation of consequences.

Hazard baseline documentation: A formal record of a facility disposition's safety basis, which includes all identified hazards and the controls established to support safe work-execution. The type and extent of hazard baseline documents will vary depending on the disposition work's scope and hazards, but typically include a combination of either a Safety Analysis Report (SAR), Health and Safety Plan (HASP), Basis for Interim Operation (BIO), Technical Safety Requirements (TSR), or other types of documented analysis (e.g., Auditable Safety Analysis [ASA]) and work packages used to plan and control work tasks.

Hazardous material: A substance or material that has been determined by the Secretary of Transportation to be capable of posing an unreasonable risk to health, safety, and property when transported in commerce and that has been so designated.

Hazardous substance: Used synonymously with the term "hazardous material," this includes any substance designated or reflected in 29 CFR 1910.120, to which exposure may result in adverse effects to the worker, public, or environment, including (1) any substance defined under Section 101(14) of CERCLA, (2) any biological agent and other disease-causing agent that after release into the environment and upon exposure, ingestion, inhalation, or assimilation by humans, either directly from the environment or indirectly by ingestion through food chains, will or may reasonably be anticipated to cause death, disease, behavioral abnormalities, cancer, genetic mutation, physiological malfunctions (including malfunctions in reproduction), or physical deformations in such persons or their offspring, (3) any substance listed by the U.S. Department of Transportation (DOT) as a hazardous material under 49 CFR 172.101 and appendixes, and 4) hazardous waste (i.e., a waste or combination of wastes as defined in 40 CFR 261.3 or substances defined as hazardous waste in 49 CFR 171.8).

Hazardous waste: As defined in 40 CFR 261, any solid waste; concentration; or physical, chemical, or infectious characteristics that may "(1) cause, or significantly contribute to, an increase in mortality or an increase in serious irreversible or incapacitating reversible, illness; or (2) pose a substantial present or potential hazard to human health or to the environment when improperly treated, stored, transported, disposed of, or otherwise managed."

High-level waste: The highly radioactive waste material that results from reprocessing spent nuclear fuel.

Hold point: A predetermined step, specified in work planning documents, that requires specific actions or hazard controls before continuing work (e.g., project activities or radiological controls).

Holding time: The maximum amount of time that a sample can be held before analysis begins.

Hot spots: Areas of radioactive contamination of higher than average concentration.

Immobilization: Treatment and/or emplacement of material (e.g., radioactive contamination) to impede its movement.

Interim storage: Storage operations for which (1) monitoring and human control are provided and (2) subsequent action in which final disposition is expected. Concepts for interim storage include bulk or compartmented storage of solid, liquid, and gaseous wastes.

Ion exchange: A chemical process involving the absorption or desorption of various chemical ions in a solution onto a solid material, usually a plastic or resin. The process is used to separate and purify chemicals, such as fission products, or to adjust the "hardness" of water (i.e., water softening).

Ionization: The process by which a neutral atom or molecule acquires a positive- or negative-charge through the loss or gain of electrons.

Isotope: A variation of an element that has the same atomic number but a different weight because of the number of neutrons it carries. Different isotopes of an element may exhibit distinctly different radioactive behaviors, but all behave the same way chemically.

Kerf: The width of the slit or notch made by a saw or cutting torch.

Low-level residual fixed radioactivity: Remaining radioactivity following reasonable efforts to remove radioactive systems, components, and stored materials that is comprised of either (1) surface contamination that is fixed following chemical cleaning or some similar process, (2) a component of surface contamination that can be picked up by smears, or (3) activated materials within structures. These components can be characterized as low level if the smearable radioactivity is less than the levels defined by 10 CFR 835, Appendix D, *Surface Contamination Values*, and hazard results shows that no credible accident scenario or work practice(s) would release the fixed or activation components of radioactivity remaining at levels that would prudently require the use of existing active safety systems, structures, or components to prevent or mitigate a release of radioactive materials.

Low-Level Waste (LLW): Waste that contains radioactivity and is not classified as high-level waste, spent nuclear fuel, or some by-product material.

Monitoring: Taking measurements or observations for recognizing the adequacy, significant changes in conditions, or performance of a facility.

Neutron radiation: High-energy neutral particles form this radiation. Neutrons can travel long distances in air and other materials and, along with gamma rays, present the greatest hazards for external exposure. Neutron radiation requires special shielding, usually light materials containing hydrogen.

Non-nuclear facility: Those activities, processes, or operations that may involve hazardous substances in such forms or concentration that a potential danger exists to cause illness, injury, or death to personnel within the facility's site boundary or to members of the public.

Nuclear facility: Those activities, processes, or operations that involve radioactive materials or fissionable materials in such form, quantity, or concentration that a nuclear hazard potentially exists to the employees or general public. Included are activities or operations that (1) produce, process, or store radioactive liquid, solid waste, fissionable materials, or tritium; (2) conduct separations operations; (3) conduct irradiated materials inspection, fuel fabrication, decontamination, or recovery operations; (4) conduct fuel enrichment operations; and (5) perform environmental remediation or waste management involving radioactive materials. Incidental use and generation of radioactive materials in a facility's operation (e.g., check and calibration sources, and use of radioactive sources in research, experimental and analytical laboratory activities, electron microscopes, and X-ray machines) would not ordinarily require the facility to be included in this definition. Accelerators and their operations are not included.

Nuclide: A species of atom characterized by its mass number, atomic number, and nuclear energy state, provided that the mean lifetime in that state is long enough to be observable.

Off-site: Beyond the boundary line marking the limits of BNL property.

Pathway: A route and sequence of processes by which radioactive material may move through the environment to humans or other organisms.

Physical hazards: Hazards that are routinely encountered in general industry and construction, and for which national consensus codes or standards (e.g., Occupational Safety and Health Administration [OSHA] or DOT) exist to guide safe design and operation without the need for special analysis to define these parameters. Physical hazards are those encountered during routine work and construction including excavation, electrical hoisting and rigging, noise, and slips, trips, and falls.

Primary wastes: Wastes that are generated as part of the cleanup of existing contaminants. Secondary wastes are generated from a supporting operation, such as using personal protective equipment.

Process equipment: The functional equipment items or systems associated directly with operating a chemical or mechanical process.

Protective clothing: Special clothing worn by persons in a contaminated area to prevent contamination of their body or personal clothing.

Radiation: (1) The emission and propagation of radiant energy; for instance, the emission and propagation of electromagnetic waves (X or gamma radiation). (2) The emission and propagation of energetic particles such as alpha particles, beta particles, and neutrons.

Radioactive material: Any material or combination of materials that spontaneously emits ionizing radiation.

Radioactive waste: Any material containing or contaminated with radionuclides at concentrations greater than the values that competent authorities would consider acceptable in materials suitable for unrestricted use or release and for which there is no foreseen use.

Radioactivity: The property of certain nuclides of spontaneously emitting radiation, either electromagnetic, particulate, or both.

Radioactivity, induced: Radioactivity produced in a substance after bombardment with neutrons or other particles. Also called *activation*.

Radiological facility: Facilities that do not meet or exceed the nuclear hazard Category 3 thresholds published in DOE-STD-1027-92, but still contain some radioactive material (see DOE-EM-STD-5502-94).

Radiological hazards: Hazards that contain radioactive isotopes that have the potential to cause harm from ionizing radiation.

Radiological protection: Protection against the effects of internal and external human exposure to radiation and to radioactive materials.

Rem: A unit of dose equivalent. A rem is numerically equal to the absorbed dose in rads multiplied by the quality factor, the distribution factor, and any other necessary modifying factors.

Repository: The site and all facilities where waste disposal takes place.

Roentgen: A unit of exposure to ionizing radiation, abbreviated "R."

Safe storage: Those actions required to place and maintain a nuclear facility in such a condition that future risk to public safety from the facility is within acceptable bounds and that the facility can be safety stored for as long as desired.

Secondary wastes: Forms and quantities of all wastes created during the treatment of primary wastes or effluents.

Shield: Material used to reduce the passage of particles or radiation. A shield may be designated according to what it is intended to absorb (as a gamma shield or neutron shield) or according to the kind of protection it is intended to give (as a background, biological, or thermal shield). It may be required for the safety of personnel to reduce radiation enough to allow counting instruments to be used.

Shutdown: The time during which a site is not in operation.

Site: The geographic area upon which the facility is located that is subject to controlled public access by the facility's licensee (includes the restricted area as designated in the NRC license).

Solidification: Conversion of radioactive and/or hazardous wastes (gases or liquids) to dry, stable solids.

Surface contamination: Radioactive and/or hazardous material adhering to an otherwise uncontaminated surface.

Surveillance and maintenance: These activities are conducted throughout the facility life-cycle phase including when a facility is not operating is not expected to operate again, and continues until phased-out during decommissioning. Activities include providing, cost-effectively, periodic inspections and maintenance of structures, systems, or components necessary to satisfactorily contain contamination and protect workers, the public, and the environment. A disposition project can be in a quiescent state of long-term surveillance and maintenance before deactivation or decommissioning.

Survey: An evaluation of the radiation hazards incident to the production, use, release, disposal, or presence of radioactive materials or other sources of radiation under a specific set of conditions.

Swarf: The amount of material (as metallic particles and abrasive fragments) removed by a cutting tool.

Task hazard analysis: An analysis of individual facility's disposition tasks (i.e., discrete units of work that comprise a project) to understand hazards that may be introduced during the work. This analysis supports the establishment of worker safety controls and development of work packages or other methods used to plan tasks.

Transuranic elements: Elements with atomic number (Z number) greater than 92.

Transuranic waste: Any waste material measured or assumed to contain more than 100 nCi/g of transuranic elements that emit alpha radiation and have a half-life of greater than 20 years.

Unreviewed Safety Issue (USI): Analogous to Unreviewed Safety Question for Radiological Facility (Facility below threshold for Nuclear Hazard Category 3). See Section 1.5, Unreviewed Safety Issue (USI) Process, for a discussion of how the process will be applied in conjunction with the BGRR-ASA.

Waste Management: The planning, execution, and surveillance of essential functions related to controlling radioactive hazardous or mixed waste, including treatment, solidification, interim or long-term storage, transportation, and disposal.

X-ray: A penetrating form of electromagnetic radiation emitted either when the inner orbital electrons of an excited atom return to their normal state (characteristic X-rays), or when a metal target is bombarded with high-speed electrons. X-rays are always non-nuclear in origin (i.e., they originate external to the nucleus of the atom).

APPENDIX A

BNL PROCEDURES FOR RADIOLOGICAL AND HAZARDOUS MATERIAL PROTECTION AT THE BGRR

APPENDIX A

BNL PROCEDURES FOR RADIOLOGICAL AND HAZARDOUS MATERIAL PROTECTION AT THE BGRR

This Appendix contains a partial list of BNL and BGRR procedures that are anticipated to be used to control radiological and hazardous materials and work. The numbering system for the BGRR Procedures Manual is still evolving, so some numbers and titles may change before the procedure for a given topic is published for use.

Additionally, as of October 1, 1999, the BGRR Decommissioning Project will be integrated into the Environmental Restoration Division (ERD), and ERD procedures will, in general, be used where available and not superseded by BGRR Project-specific procedures.

BGRR-PM 1-4, *Review, Revision and Approval of BGRR Project Instructions and Procedures*

This procedure will provide the instructions and format for preparing procedures, instructions, work lists, or guidelines that will be used by technicians or other staff members for the Project.

BGRR-SI-0920, *Documenting, Reporting, Tracking, and Dispositioning Nonconformance and Data Discrepancies*

The scope of this instruction covers the guidance for conducting periodic self-assessments of the Project surveys and establishes a deficiency-reporting system. The system assists management in evaluating root causes, initiating corrective actions, tracking overall Project performance, and incorporating lessons-learned into the work.

BGRR-SI-0940, *Indexing, Classification, Distribution, Retention, and Storage of BGRR Project Records*

This instruction will describe the methods used to control and file documents that are produced during the Project surveys and are essential to the quality of the Project report.

BGRR-SI-0104, *Survey and Sampling Techniques for Structures and Systems*

This instruction will teach technicians to perform survey measurements on structures and systems. It will include techniques for scans, total surface contamination, exposure rates, removable contamination smears and special samples, and also alarm-response requirements.

BGRR-SOP-0201, *In-Plant Radiological Surveys to Support the Radiological Project Program*

This instruction will describe specific methods to perform radiological surveys by sampling within the BGRR facility. Where possible, reference will be made to other existing procedures, instructions, or work controls with which survey personnel are familiar.

BGRR-SOP-0202, *Plant Radiological Surveys in Support of the Project Program*

This instruction will set out the specific methods necessary to perform radiological surveys by direct measurement of the BGRR facility. Where possible, reference will be made to other existing procedures, instructions, or work controls with which survey personnel are familiar.

BGRR-SOP-0310, *Survey Instrument Calibrations and Use*

Procedures for instrumentation used for the Project include source checking, operation, downloading, probe operation, measurement guidelines, and calibration guidelines for use.

BGRR-SI-0320, *Quality Control Methods*

This instruction will cover the performance of quality-control replicate survey measurements and the collection of quality-control material samples associated with the Project surveys.

BGRR-SOP-0901, *BGRR Monitoring and Surveillance Procedure*

Procedures for routine monitoring and surveillance operations at the BGRR including water- intrusion-level surveillance monitoring, and BGRR Complex physical-inspections surveillance monitoring.

BGRR-SOP-0902, *Safety Evaluations for Unreviewed Safety Issue Determinations*

Procedure for evaluating activities that may be outside the scope of the Safety Authorization Basis Document for the BGRR Decommissioning Project, and their potential impact.

BGRR PM 2.12, *Work Planning and Control System Procedure*

Procedure for implementing work control in accordance with ES&H manual guidance.

BSS-1, *Procedure for Hot Laundry Operations*

BSS-SOP-0002, *Vehicle Radiation Monitor Procedure*

BSS-SOP-0004, *Requirements for Notification*

BSS-SOP-0006, *BSS Termination of Film Badge Service*

FS-SOP-1000, *Radiation Survey Techniques*

FS-SOP-1001, *Contamination Survey Techniques*

FS-SOP-1002, *Hot Cell Radiation Streaming Survey*

BSS-SOP-1030, *Smear Counter Calibration and Operation*

BSS-SOP-1031, *Eberline BC-4 Beta Counter Operation*

FS-SOP-1040, *Airborne Radioactivity Sampling/Analysis*

FS-SOP-1050, *Radiological Survey for Radioactive Waste*

FS-SOP-1060, *Sealed Radiation Source Leak Check*

BSS-1070, *Portable Air Sampler Operation*

BSS-1080, *Laboratory Hood Surveys*

BSS-SOP-1090, *Radiological Surveys-Hazwaste Containers*

BSS-SOP-2000, *Health Physics Instrument Inventory and Control*

FS-SOP-2010, *Periodic Instrument Response Check*

BSS-2020, *Ludlum Floor Model 239-1F Set-up and Operation*

BSS-2030, *Procedure for Charging Self-Reading Dosimeters*

BSS-SOP-2040, *Sludge Radiation Monitor Procedure*

FS-SOP-3000, *Radiological Posting Requirements*

FS-SOP-3010, *Labeling, Documentation, and Handling of Radioactive Material and Radioactive Sources*

BSS-4000, *Protective Clothing and Equipment - IH and Haz*

FS-SOP-4001, *Protective Clothing & Step-off Pads - Rad*

BSS-SOP-4002, *Use and Issuance of Respiratory Equipment*

BSS-SOP-4011, *Personnel Contamination Reporting*

FS-SOP-4020, *Use of Dosimetry*

FS-SOP-4031, *Radiation Work Permit*

APPENDIX B

DETAILED FACILITY INFORMATION

APPENDIX B

DETAILED FACILITY INFORMATION

This appendix gives detailed information on the construction and operations history of various components and structures within the BGRR Complex. It supplements the brief description given in Section 2.1 of the main document.

B.1 Buildings

B.1.1. Building 701, Reactor Building (Figure B.1)

This building is a concrete, steel, and brick structure that houses the reactor pile, support equipment and systems, and administrative offices. Parts of the building were contaminated during operations. The walkway areas of the building are routinely surveyed. Known areas of contamination are posted to limit access. Radioactivity levels are the following: general walkways <50 μR/hr, <1000 dpm/100 cm^2 beta/gamma, <20 dpm/100 cm^2 alpha; inside posted Contamination Areas up to 100,000 dpm/100 cm^2 beta/gamma; inside posted High Contamination Areas >100,000 dpm/100 cm^2 beta/gamma and up to several mR/hr, and inside posted Radiation Areas from 5 mR/hr up to 100 mR/hr. No High Radiation Areas (>100 mR/hr) are present or posted in this building. Access is controlled by restricted key distribution to a locked building-entry door.

B.1.2 Building 702, Reactor Pile (Figure B.2)

This is the designation for the graphite Pile, the control rods, the Biological Shield, and associated equipment. The control-rod areas are contaminated and are posted areas. The faces of the reactor are contaminated to various levels, and are posted accordingly. Building 702 is entirely enclosed within Building 701, and so its access is also controlled.

B.1.3 Building 703, Reactor Laboratory Building with East and West Wing

Building 703 is not within the scope of the Project, nor is it discussed in the Project Management Plan. It contained the researcher areas. Contamination in this building was contained and minimal during the reactor's operations. Presently, the building is used for research and analytical-laboratory work. There is an interface between Buildings 701 and 703 which may be removed and replaced by permanent walls; common support services such as ducting for heating, ventilation and air conditioning (HVAC), electrical conduits, water and sewage piping will be limited to the extent practical.

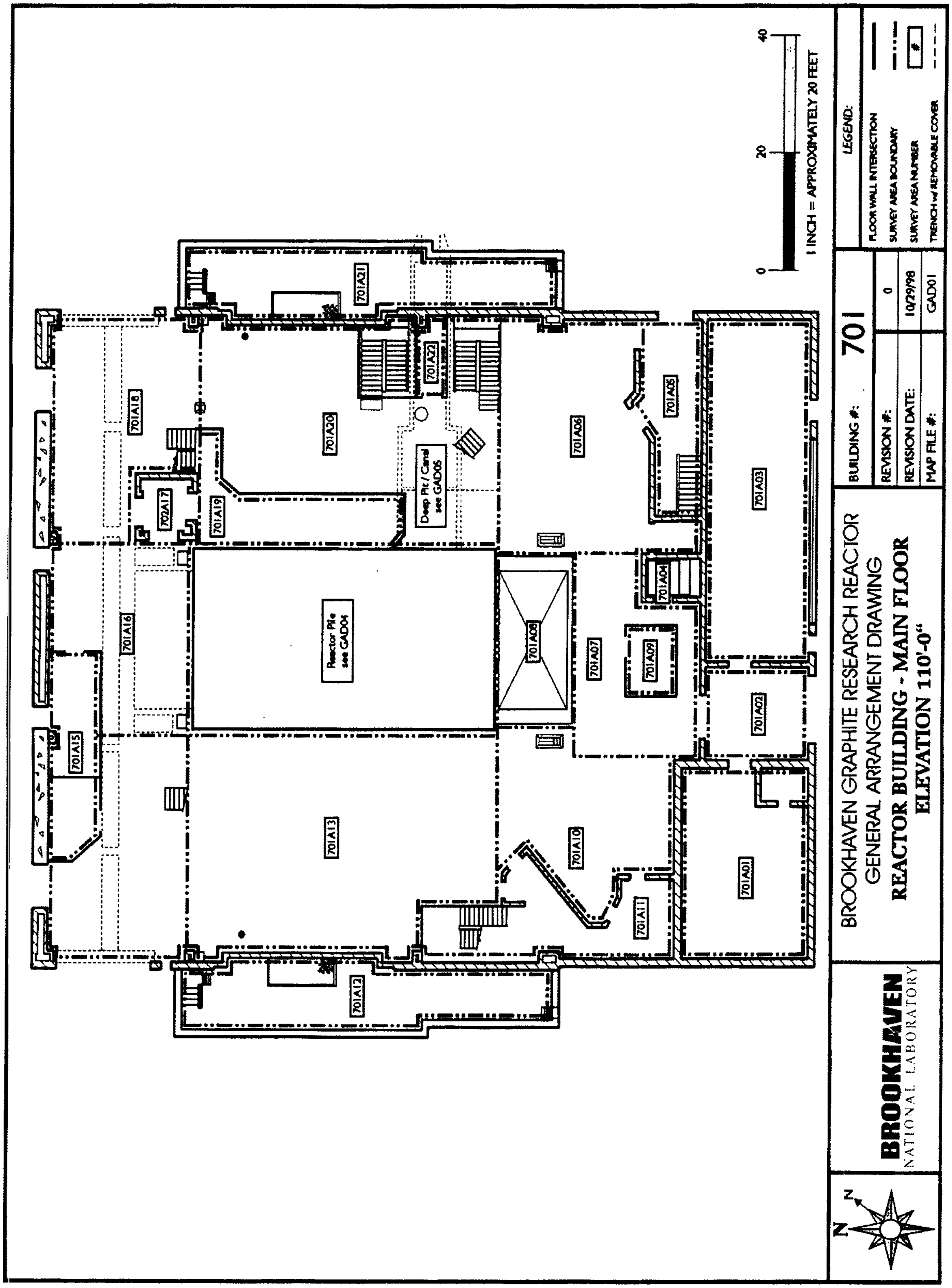

Figure B.1. Building 701, Reactor Building

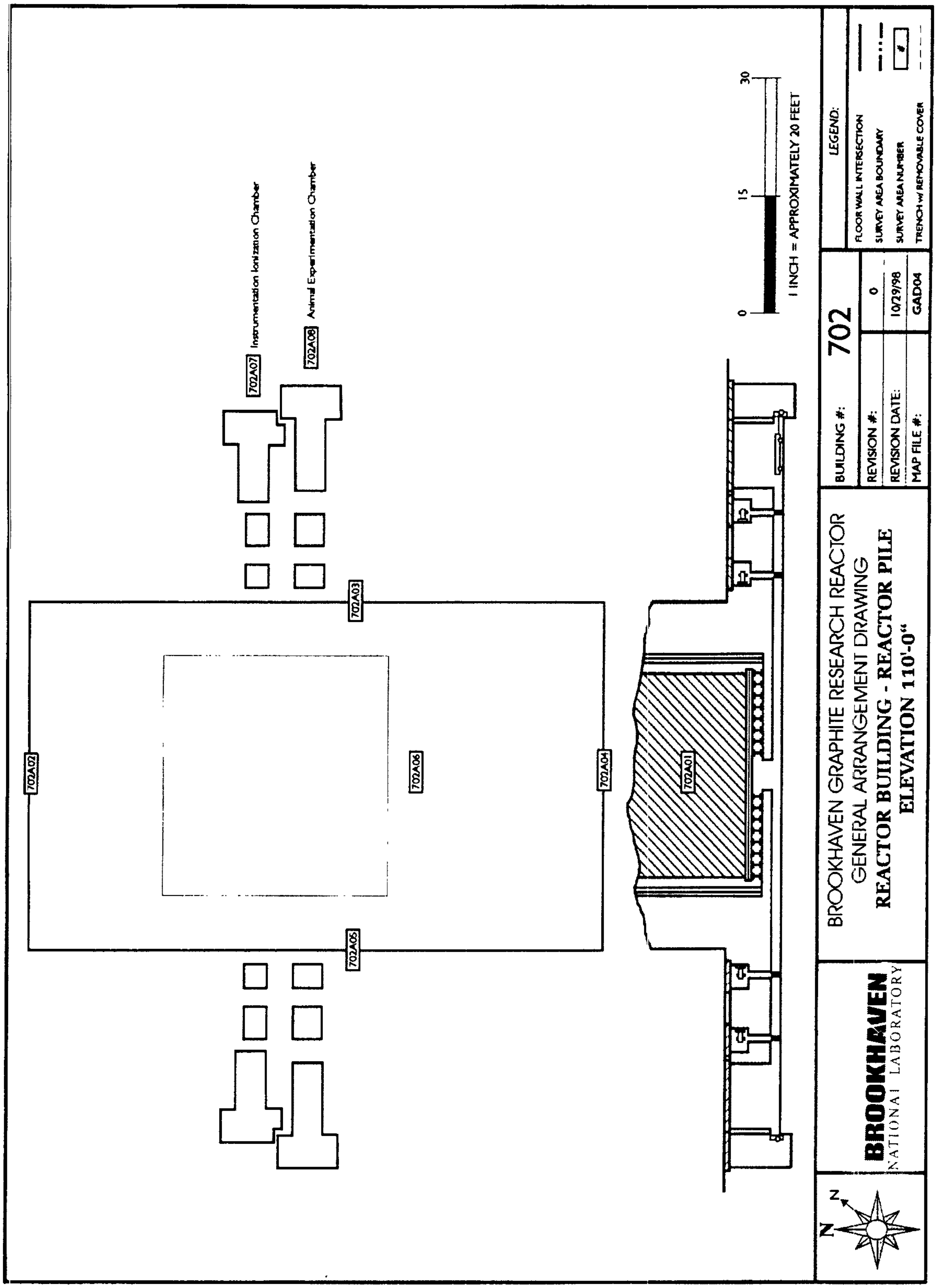

Figure B.2. Building 702, Reactor Building Pile

These changes will allow the continued use of all or most parts of Building 703 while work takes place in Building 701. Access to Building 703 is not restricted, but passage through the interface to Building 701 is controlled through the locked entry door of Building 701.

B.1.4 Building 704, Fan House (Figures B.3 to B.5)

This building contains the five motors and fans that were the motive force for the cooling-air supply to the BGRR Pile. Air ducting from the Pile is located on the roof of the structure, with the equipment inside the building. The fans discharged under the building into duct work which exhausted cooling air into the base of the stack. The interior of this section of duct work has various levels of fixed- and removable-contamination, as do the fan rooms within the building. Due to the presence of electrical switchgear and equipment within this building which is owned by the High Flux Beam Reactor (HFBR), a formal Memorandum of Agreement (MOA) was signed by representatives of the BGRR Decommissioning Project and the Reactor Division defining the protocols for BGRR's cleanup within the building. Appendix C contains a copy of the MOA. Access is limited by restricted key distribution and a locked entry-door. The building has posted Contamination Areas. The Instrument Room is a posted Radiation Area. The gravel around the building also is posted as Underground Radioactive Material Area. Figures B.4 and B.5 show details of areas of responsibility, drain lines to the Pile Fan Sump, and structural materials.

B.1.5 Building 708, Instrument House (Figure B.6)

The Instrument House contained the instrumentation monitoring the cooling ventilation system, including manometers to monitor differential pressure across filters and downstream coolers. The internals of this building contain radiological- and hazardous-materials. The building and the surrounding grounds were posted as an Underground Radioactive Materials Area; surveys show radioactivity over 50 μr/hr up to 1.5 mr/hr. The non-radioactive hazardous material is asbestos and mercury. This building is no longer used. Access is controlled by restricted key distribution and locked entry door.

B.1.6 Building 709, Canal House and Outdoor Pad (Figure B.7)

The Canal House was used to store and prepare fuel, irradiated equipment, and radioactive materials for shipment and disposal. The inside area contains fixed and removable contamination. The outdoor pad area has fixed contamination under several layers of asphalt and concrete. The outside area around the Canal House is posted as a Controlled Area - TLD Required; an Underground Radioactive Material Area survey showed >50 μR/hr up to 300 μR/hr. The Canal House is connected to the Water Treatment House on its north wall. Entry to the Canal House is controlled by restricted key distribution and locked-entry door.

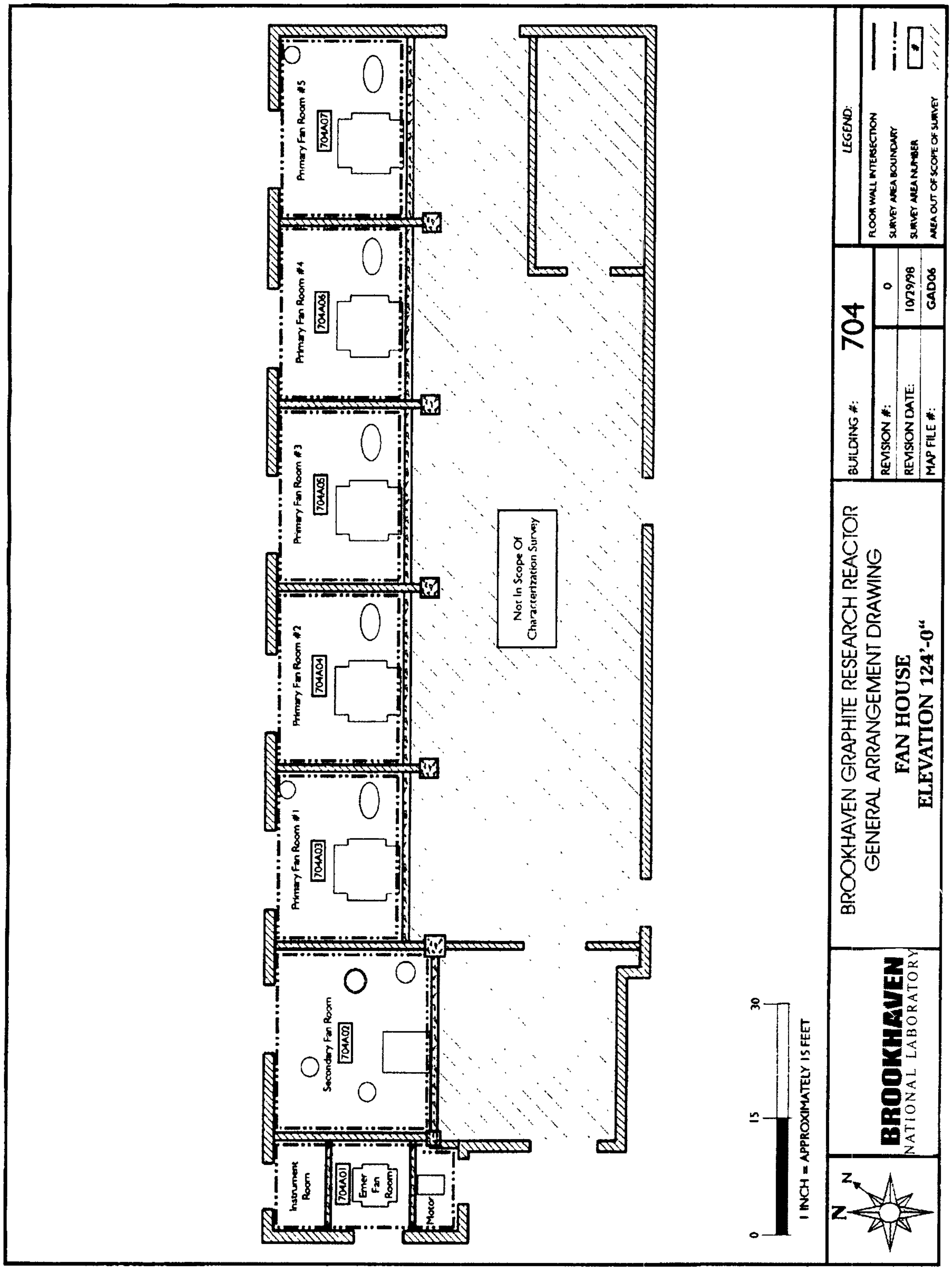

Figure B.3. Building 704, Fan House

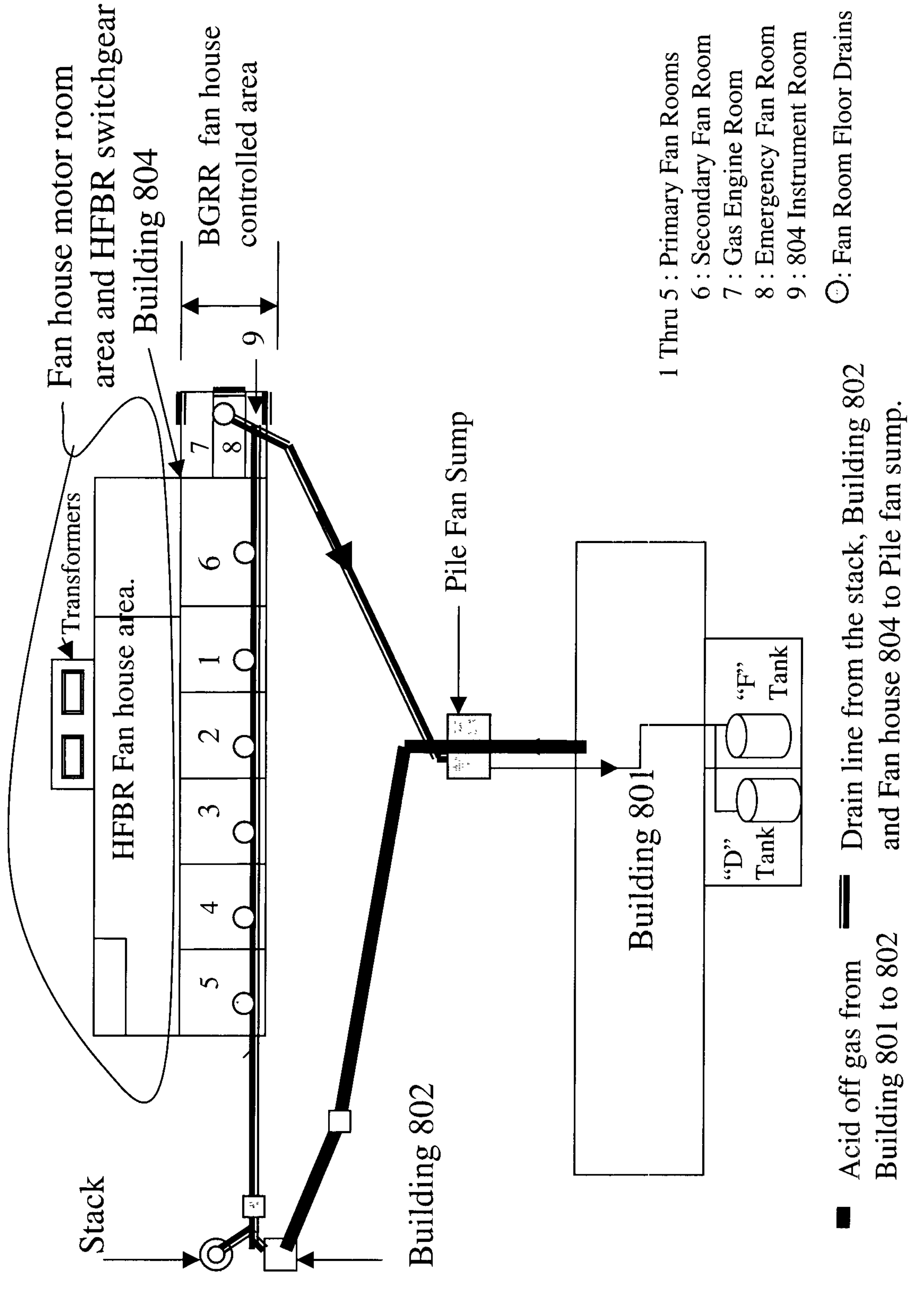

Figure B.4. BGRR Fan House Floor Drain System to Pile Fan Sump, Building 704

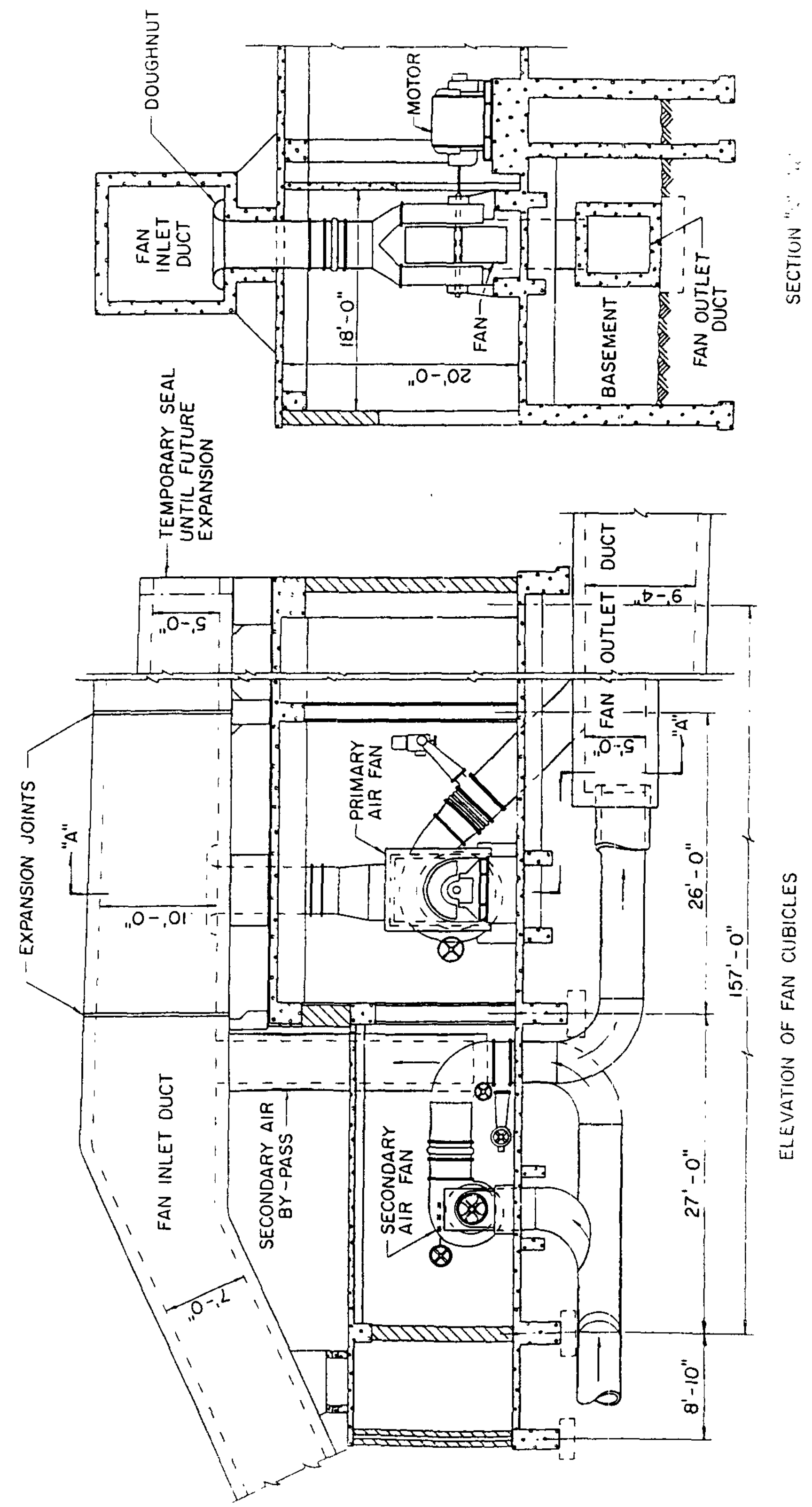

Figure B.5. Fan House Section Showing Primary Air Fan, Building 704

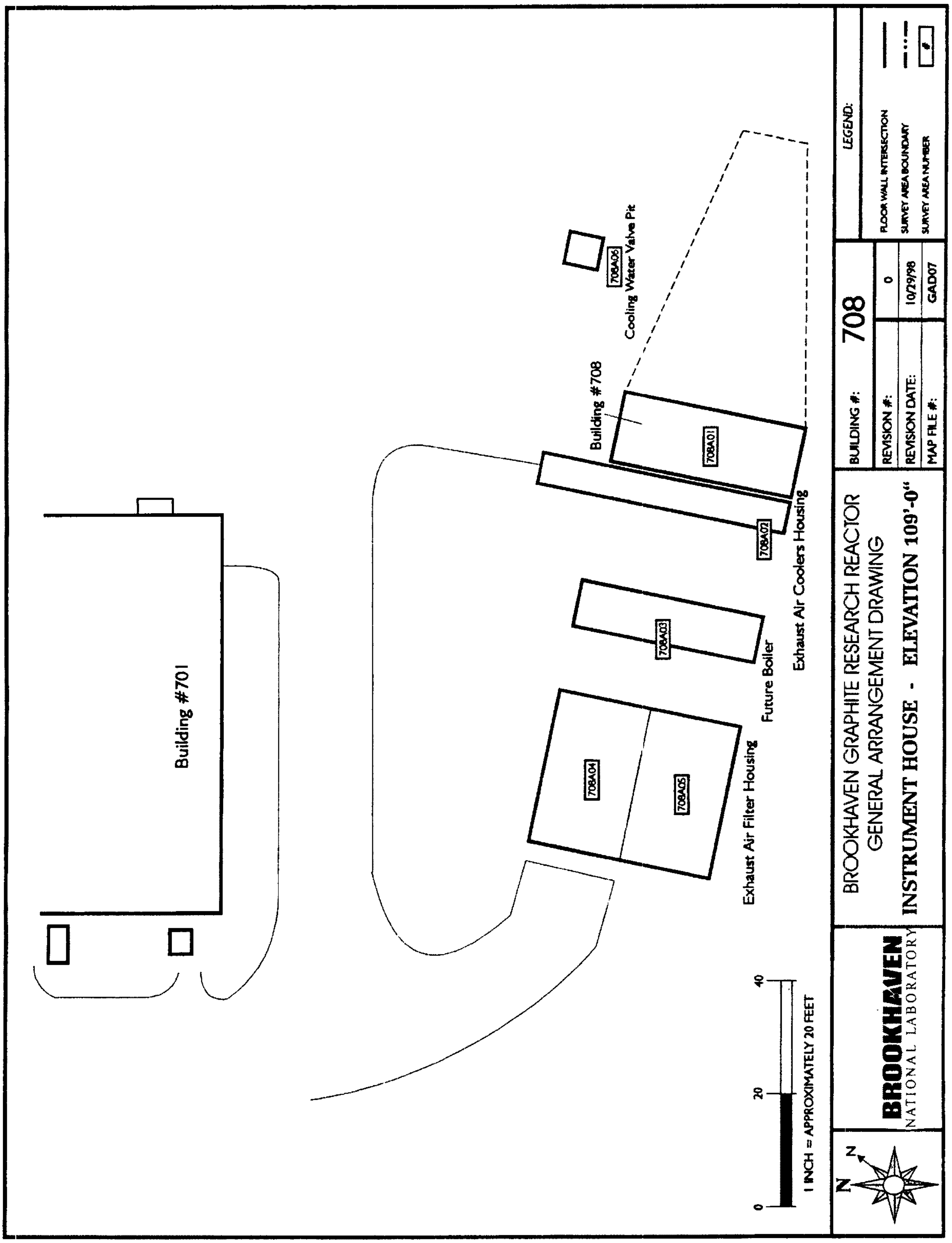

Figure B.6. Building 708, Instrument House

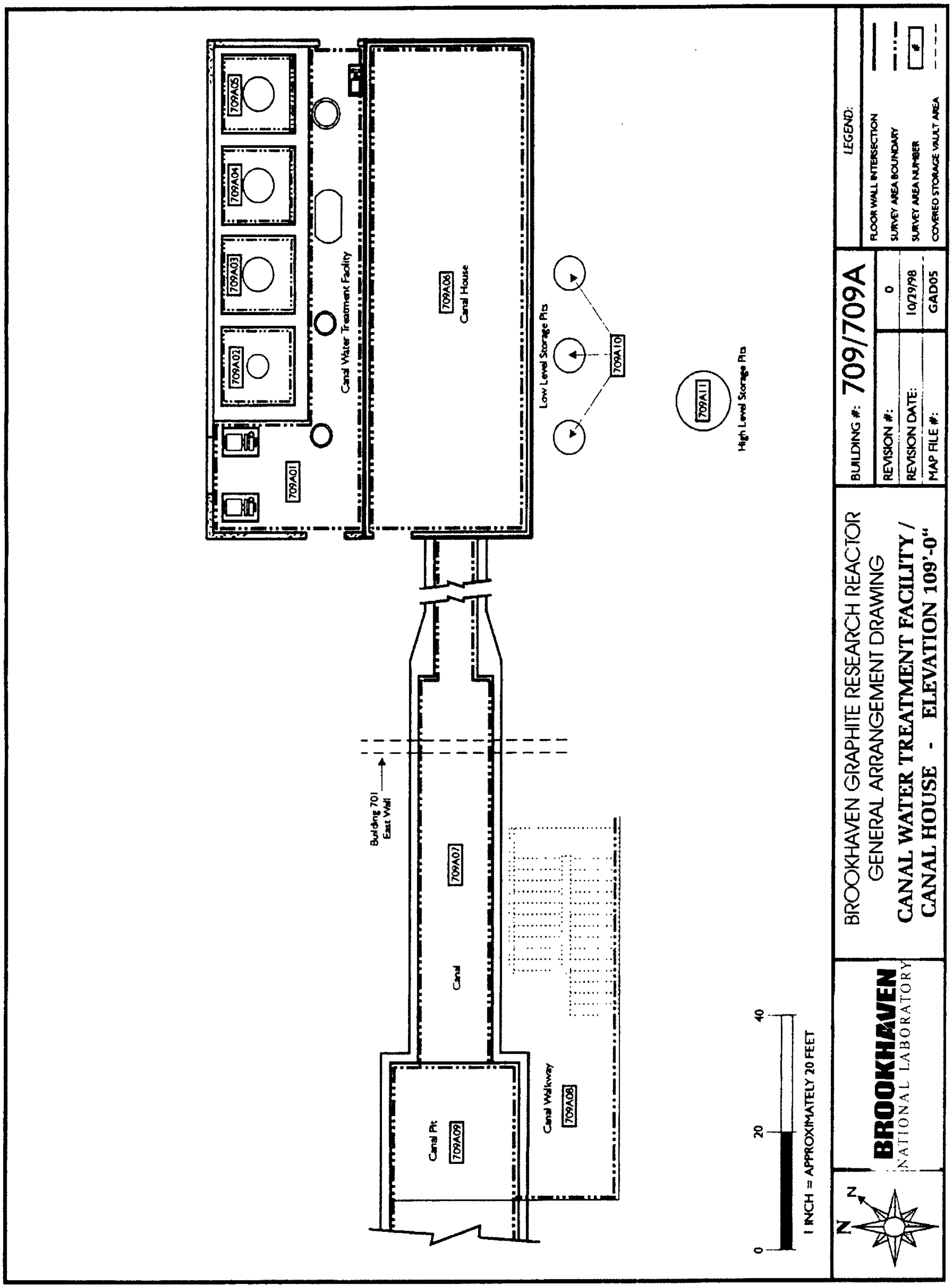

Figure B.7. Building 709, Canal House and Outdoor Pad

B.1.7 Building 709A, Water Treatment House and Outdoor Pad (Figure B.8)

This area was used to treat water used in the canal. This building's outdoor pad area is connected to Building 709's outdoor pad area and is known to contain fixed contamination under several layers of paint and asphalt. Survey data, circa 1986, showed radiation levels 2-70 mr/hr inside the Canal House on the cask washdown/decontamination area, with possible contamination of the soil around buried drain lines and under floor cracks. A May 1999 survey and cleanup of hot spots showed maximum levels of 70 mrad/hr beta radiation at a height of 30 cm. Access to the Water Treatment House is controlled by restricted key distribution and locked entry-door.

B.2 Major Reactor Systems

B.2.1 Graphite Pile

The graphite structure has the overall dimensions of a 25-foot cube. It is divided into two halves by a vertical gap 3-1/8 inches (8.0 cm) wide. It is built up of 75 layers of blocks 4 x 4 inches, of various lengths up to 45 inches, laid horizontally. Figure B.9 shows an isometric cutaway view of the graphite structure [1].

The even-numbered layers, which contain the channels for the fuel assemblies, are made up almost entirely of long blocks. Short blocks were used mainly in the odd-numbered layers. Most of the blocks were laid parallel, with their long axes north-south, with the following exceptions: sufficient blocks are run crosswise in the forty-first layer to span the opening for the removable core (described below). For the 30 experimental holes (five rows of six holes each), each 4-inches square, which run horizontally east-west through the graphite structure in the odd-numbered layers, the sides of the holes were formed by long blocks running east-west. The sides of the diagonal horizontal openings for the control rods were similarly formed by long blocks laid diagonally. The faces of the abutting blocks were cut at 45 degrees to fit. Figure B.10 shows the experimental penetrations and the control rod racks.

Longitudinal (vertical) joints were staggered symmetrically between successive layers by making the outside blocks in the even-numbered layers 6 inches wide instead of 4 inches. The end joints were variably staggered, both within a layer and between successive ones.

Channels - The 1368 channels, which carried the fuel assemblies and cooling air, run north and south through the graphite. There are 37 rows of 37 holes each, except for the center hole in the 18th row that is occupied by the 12-inch-square removable core. The channels are symmetrically arranged on 8-inch centers in a square array, starting 6 inches from the graphite surface. They have a circular cross-section of 2.67 inches in diameter, and were made by a milling cutter with a 1.355-inch radius in two adjacent blocks. The circular

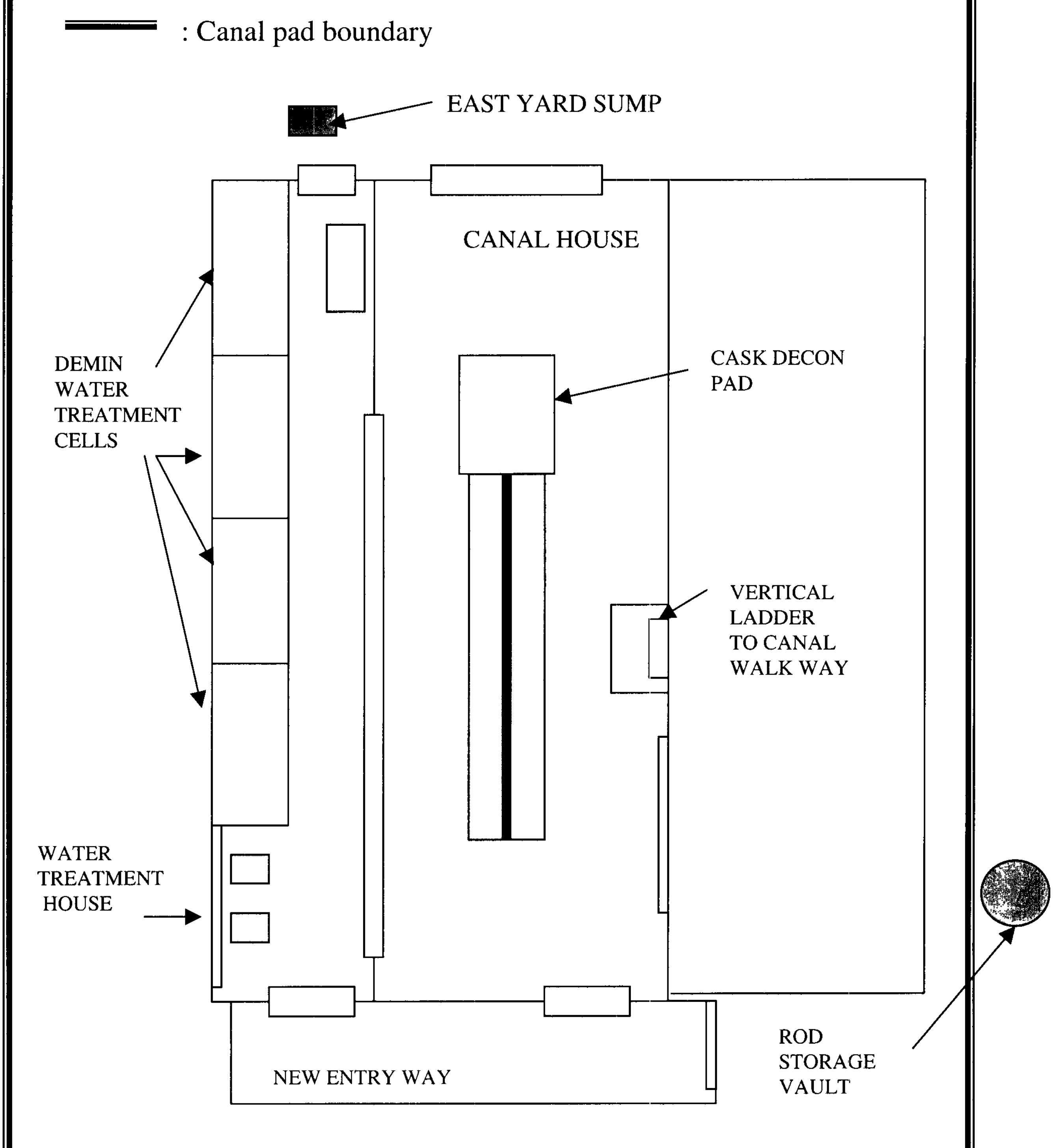

Figure B.8. Building 709A, Water Treatment House and Outdoor Pad

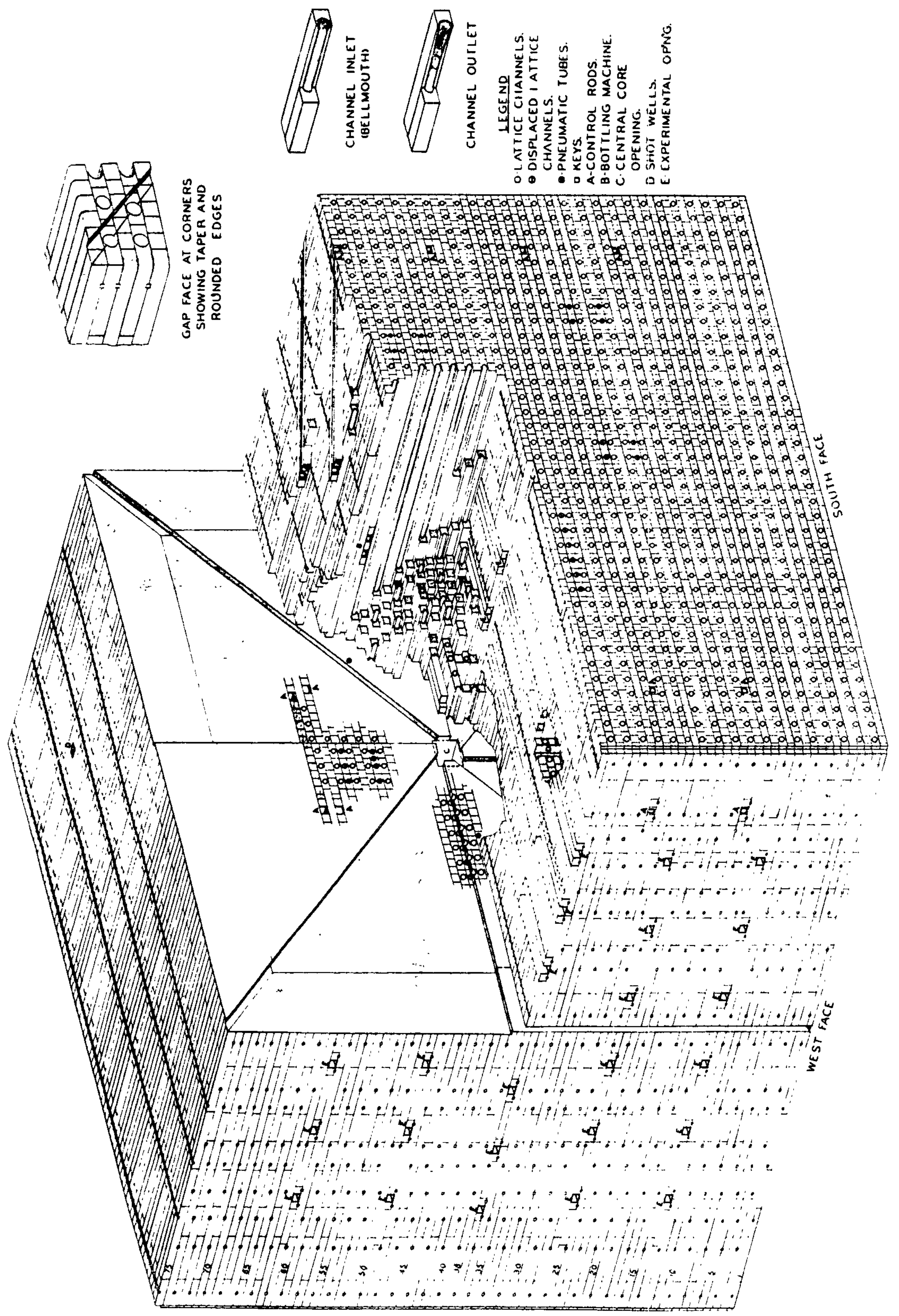

Figure B.9. Isometric View of Graphite Structure

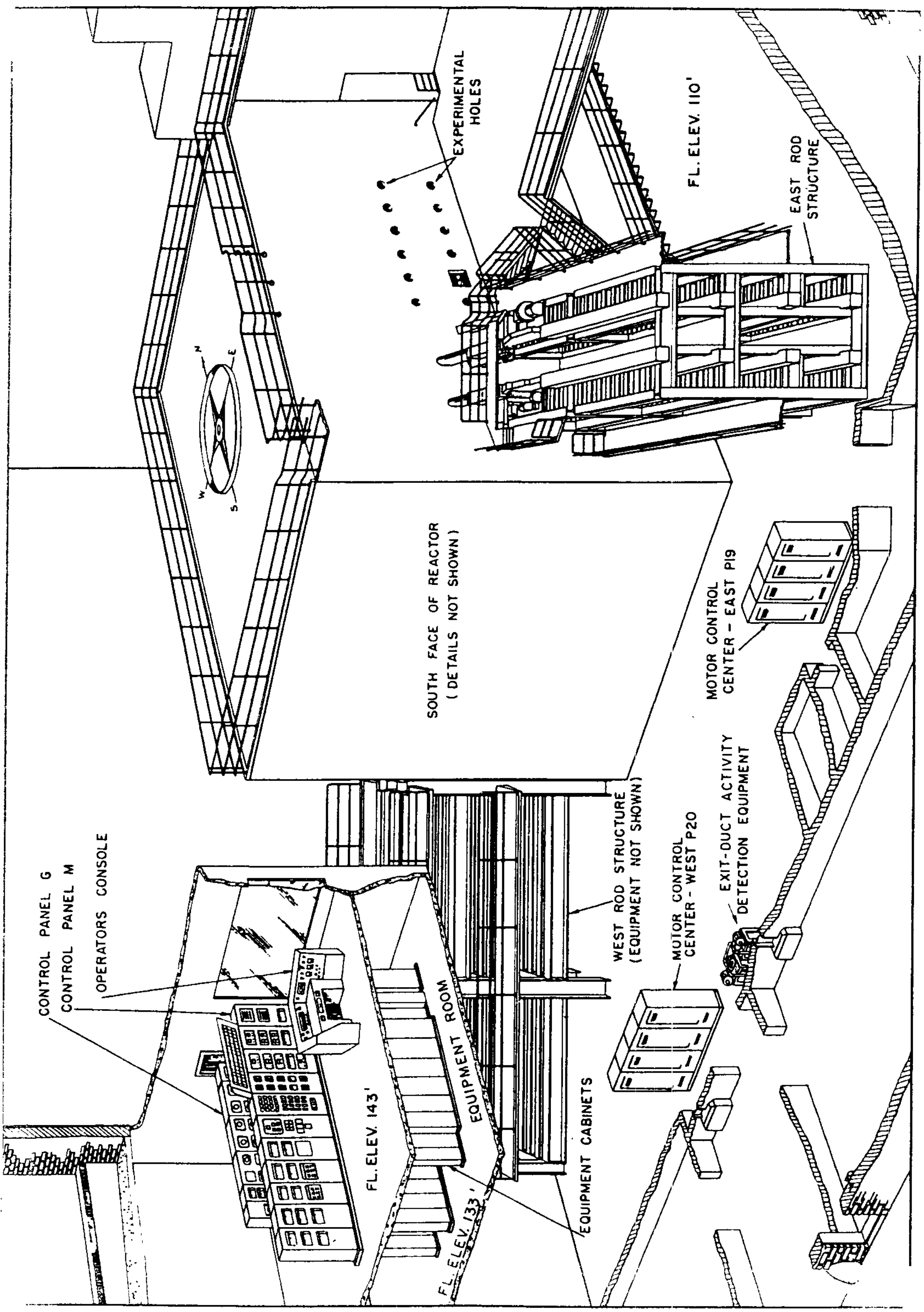

Figure B.10. Location of Instrument and Control Equipment

edges between blocks were chamfered (0.005 inch and 45°) to avoid the possibility of a shoulder caused by shifting of the graphite that might block the fuel elements as they were pushed through the channel. The channel ends were expanded in two ways: (1) the inlet mouth at the gap had a 3-1/4-inch radius tangent to the cylindrical surface at a point 1-25/32 inches from the end; (2) the outlet had an overall 7° taper starting 6-7/8-inches from the plenum end of the channel, corresponding to a terminal diameter of 3-1/2-inches.

One or more of the outer channels was not charged with fuel. The tapered channel outlet was filled with a tapered graphite plug, 7 inches long, 3-1/2-inches in diameter at the large end, with a 6° 48' included angle of taper. This plug was penetrated by a 3/8-inch aluminum bolt, used for inserting and removing the plug.

Experimental Penetrations - The BGRR was primarily a research instrument. This fact influenced the design in many ways, such as the choice of an air-cooled graphite-moderated type of reactor to obtain large dimensions, and of high-density concrete to facilitate access to the neutron flux by reducing the shield's thickness. The reactor had a large number of experimental facilities, supporting an extensive research program.

The experimental features that are built into all six faces of the reactor are indicated below:

Experimental holes	east, west, and north faces
Target conveyor	east and west faces
Pneumatic tubes	north face
Removable central core	north face
Animal and instrument tunnels	bottom face
Removable roof section	top face
Unused fuel channels	south face

These experimental facilities were served by balconies on the north, east, and west reactor faces, by a freight elevator at the northeast corner of the reactor, and the charging elevator on the south face.

The experimental features are located mainly in the Biological Shield, and, to a lesser extent, in the graphite structure.

Experimental Holes - Extending through the graphite from the east to the west faces were 30 experimental holes which lined up with the corresponding openings on the east and west faces of the Biological Shield. Each opening was designated by a letter and two numbers showing its location. Thus, E-24 was the fourth hole from the south in the second row from the bottom on the east face. Since the gap faces are not plane surfaces extending straight through from east to west, but appear as triangular surfaces alternately raised in relief or recessed, the openings of experimental hole 30 on the east and west face of the reactor do not coincide but are vertically displaced from each other. These holes were employed to irradiate research samples at different intensities.

Animal and Instrument Tunnels - The experimental openings in the graphite structure were limited in size by the lattice requirements. To expose large samples to radioactivity, two chambers were provided underneath the reactor. One of these, known as the animal tunnel, was employed to irradiate animals. The other, known as the instrument tunnel, was used to irradiate miscellaneous large samples, to contain instruments, and was serviceable in several ways. The two tunnels are located in the layer of concrete (5 feet 10-1/4 inches thick) between the top of the buttresses and the bottom of the I-beams supporting the reactor.

The two tunnels were similar in design and were symmetrically located with respect to the east-west reactor center line, but differed in size. The tunnels run east-west and extend beyond the Biological Shield on both sides. The sample was placed in a four-wheeled cart and transported to the target area at the tunnel's midpoint. The target area had an opening cut through the bed plates, the flanges of the I-beams, the concrete, and the roof at the tunnel lining; for the animal tunnel, this opening was 3-feet long (east-west) by 2-feet wide, and for the instrument tunnel it was 3-feet long by 1-foot wide. The only obstructions to radiation through these openings were three 1/8-inch plates of 24 ST aluminum sheet. One of the aluminum sheets was sealed in the concrete 9 inches below the I-beams (elevation 106 feet 1-1/4 inches) and contains a 1-inch-diameter hole allowing sufficient air-flow for ventilation but not excessive for nonfiltered air leakage. One of the other two aluminum sheets was fastened to the underside of the upper bed plate, and the other to the topside of the lower bed plate.

The animal tunnel was located 3-feet south of the Pile center line (center line distance) and the instrument tunnel was 3-feet north. The animal tunnel was 2-feet square and its axis was 5 feet 3-3/4 inches below the floor level of 110 feet 0 inches, while the instrument tunnel was 1-foot square and its axis was 4 feet 9-3/4 inches below the floor.

Control Rods - The BGRR had sixteen boron-steel control rods. They penetrated the reactor horizontally in directions parallel to the diagonals of the reactor's base. Figure B.11 shows the control-rod insertions.

Boron-Shot Wells - A boron-shot wells system was provided to shut down the reactor in the event of an emergency in which the control-rod shutdown system was prevented from operating properly. The system's function was to add a sufficient quantity of poison to the reactor, in the form of boron-steel shot, dropping by gravity into wells in the reactor, to

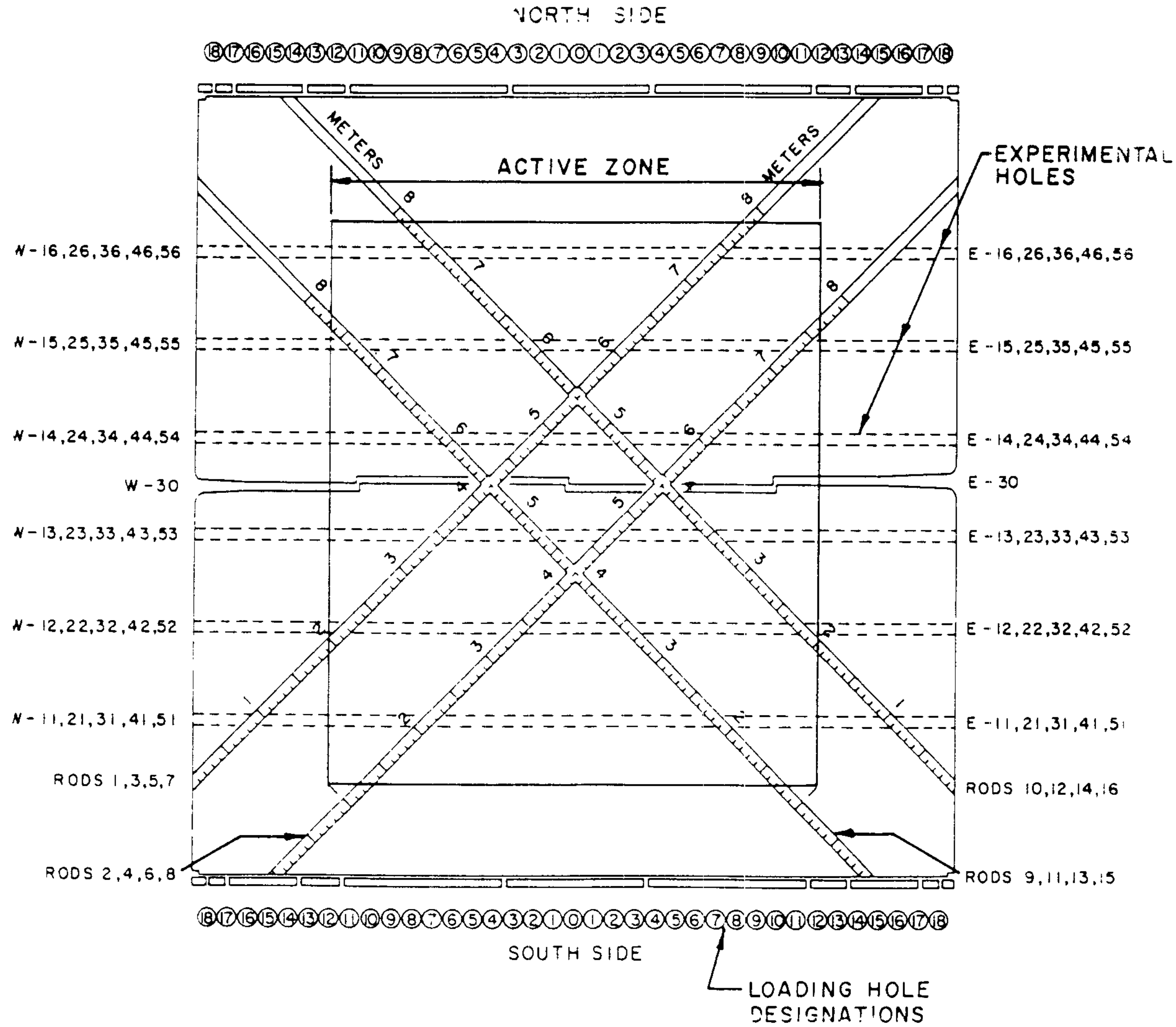

Figure B.11. Control-Rod Insertions

shut it down. Figure B.12 shows the assembly of a vertical boron-shot well, and Figure B.13 is a diagram of the assembly gap of a boron-shot well.

There are two vertical boron shot wells located in the graphite, and two diagonal boron-shot wells in the gap. The effectiveness of all four wells is 1.8% $\Delta \frac{k}{k}$.

Approximately 1,050 pounds of 5/16-inch diameter boron-steel balls were used in the reservoirs. They were made from hot drawn boron-steel wire and have the same composition as the boron steel used in the control rods. The balls were cadmium-plated to protect them against rust.

B.2.2 Biological Shield

The Biological Shield is 55-feet long by 37-feet 6-inches wide by 33-feet 7-inches high, extending from elevation 106 feet 9 inches (3 feet 3 inches below the main floor) to elevation 140 feet 4 inches. The shield consists of an inner layer of steel 6-inches thick (two separate plates in some areas), 4-feet 3-inches of high-density concrete (with steel punchings and limonite iron ore), and an outer casing on the sides (but not on top) of 3 inches of steel plate. There is also a 12-inch thick by 20-inch wide belt of steel around the gap in the Pile.

The shield is in much the same condition as it was during reactor operation with the following exceptions:

- The experimental holes have been closed or plugged
- The ports for the control rods are covered and tack-welded

Since the reactor was shut down in 1969, the irradiated shield materials have had more than 30 years to decay. Also, due to the relatively large size of the graphite cube and the relatively large diffusion length, the shield was mostly bombarded with thermal neutrons. The gap-belt steel also was hit by fast neutrons. For the most part, the thermal neutrons were absorbed by the iron in the 6-inch interior steel shield, creating Fe-59 (half-life = 45d) which decays into Co-59 (stable) and Fe-60 (half-life = 300,000 years) which would still exist. However, the amount of iron existing in this form is expected to be small because of the low production rate of Fe-59. Since the half-life of Co-60 is 5.26 years, much of it has decayed. Moreover, for Fe-55, which has a half-life approximately half as long as Co-60, twice as many half-lives have passed. Therefore, based on the half-lives of the typical neutron-activation products produced and the passage of time since the reactor last operated, residual activation-product radioactivity should be low.

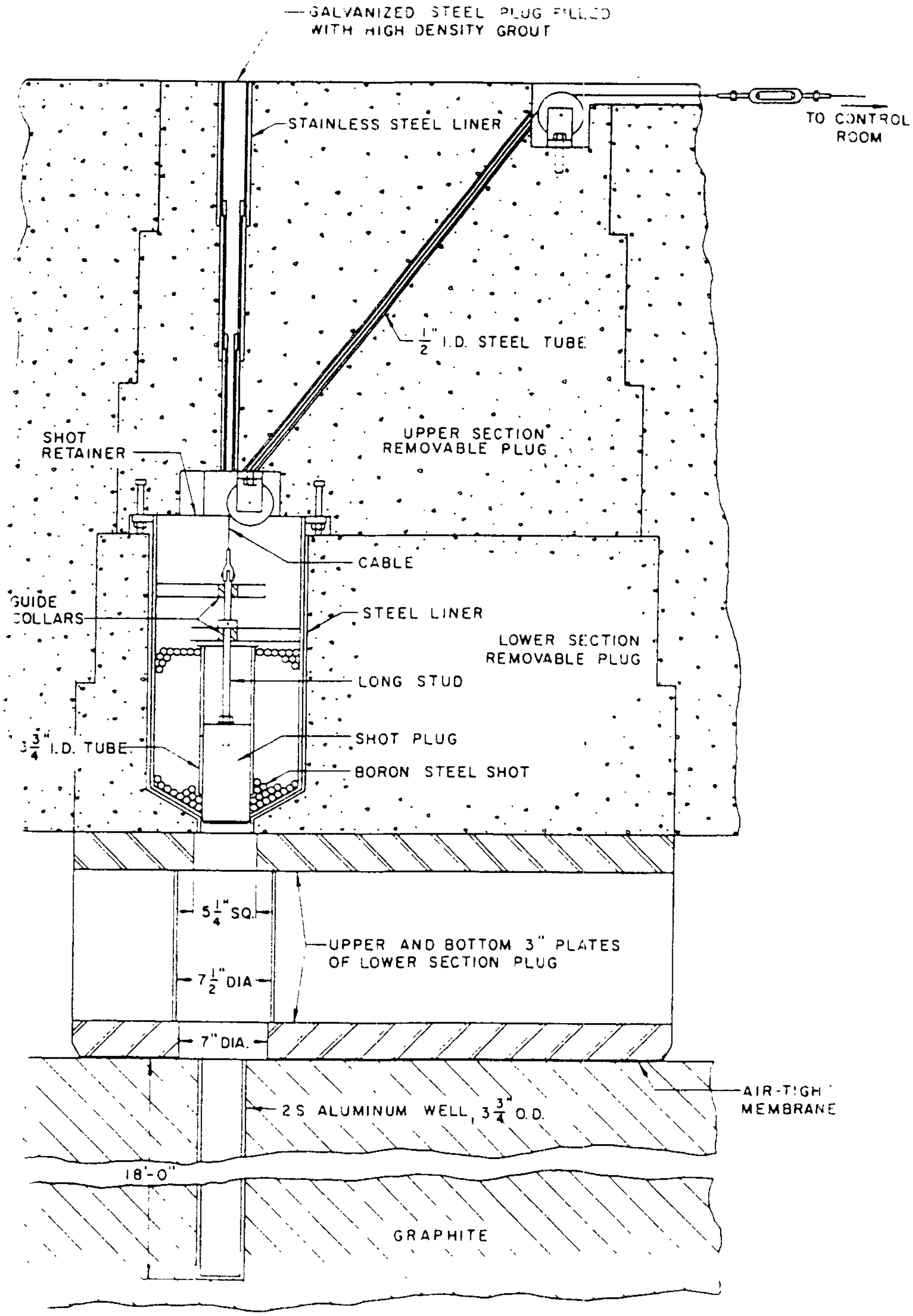

Figure B.12. Assembly of a Vertical Boron-Shot Well

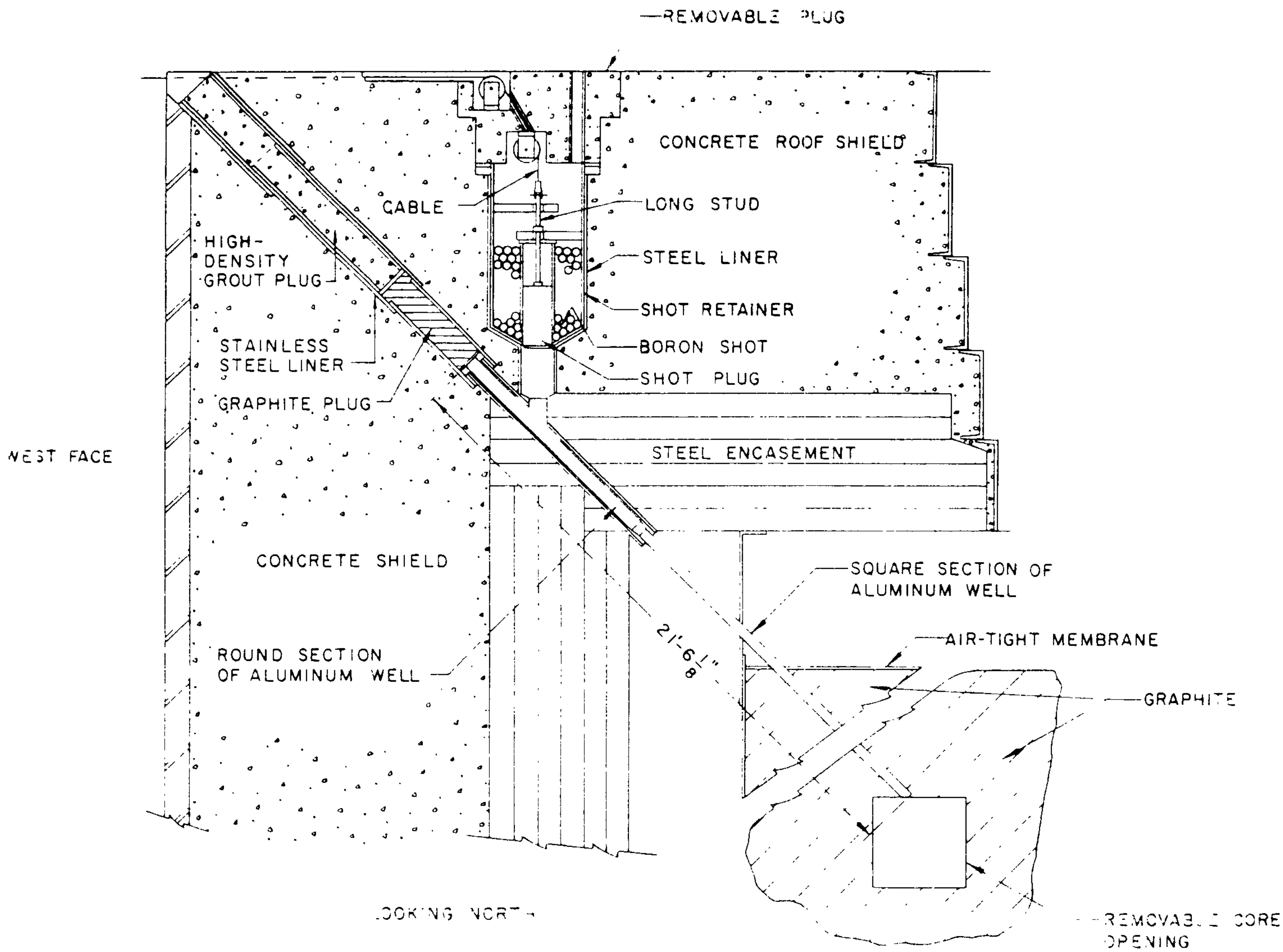

Figure B.13. Assembly Gap of a Boron-Shot Well

The experimental holes, charging tubes, target conveyor, and removable core pass through the shield. Since these openings are generally lined with steel, they protected the biological shield from contamination; however, they are expected to be contaminated.

A portion of the biological shield lies beneath the graphite Pile. It consists of two 3-inch steel-bed plates supported by thirteen I-beams which are tied to the concrete pedestal by anchor bolts. The steel plates are tied to the I-beams by a series of shims and bolts. The I-beams are supported by cross braces that restricted I-beam movement caused by the realignment of the graphite cube when the gap-adjustment machine operation was operated or by thermal stress. (See Figure B.14, "Section of Biological Shielding," and Figure B.15, "Plan of Reactor.")

Since the final shutdown in 1969, the general area outside the reactor and the reactor faces have been decontaminated.

B.2.3 Control-Rod-Drive Mechanisms

There are two assemblies of control rods, rod-drive mechanisms, and support structures: assembly one is on the southeast corner of the reactor, and the other on the southwest corner. During operation, these two mechanisms were operated concurrently for shutdown. Each assembly consisted of the following parts:

- Eight control-rods per pile half,
- Four personnel passageways built into the support structure,
- Lead shielding for the control rods,
- Eight control-rod-drive mechanisms per pile half, and
- Support structure.

In 1971, the sixteen control rods were cut from their drive mechanisms and completely inserted into the graphite Pile, whereupon their ports were covered and tack-welded. Within the last 10 years, the control-rod-drive structure was decontaminated (except under the lead shielding where some contamination may exist), and the drives were electrically disconnected.

B.2.4 Reactor Air-Cooling System (Figures B.16 to B.19)

Cooling-air drawn through roughing filters was pulled through the graphite to remove heat produced by the fuel and cool the graphite. The heated air then flowed out of the reactor into two underground concrete exhaust-ducts connected to the plenum, then through in-duct filters and coolers. Building 708, Instrumentation House, contains the support

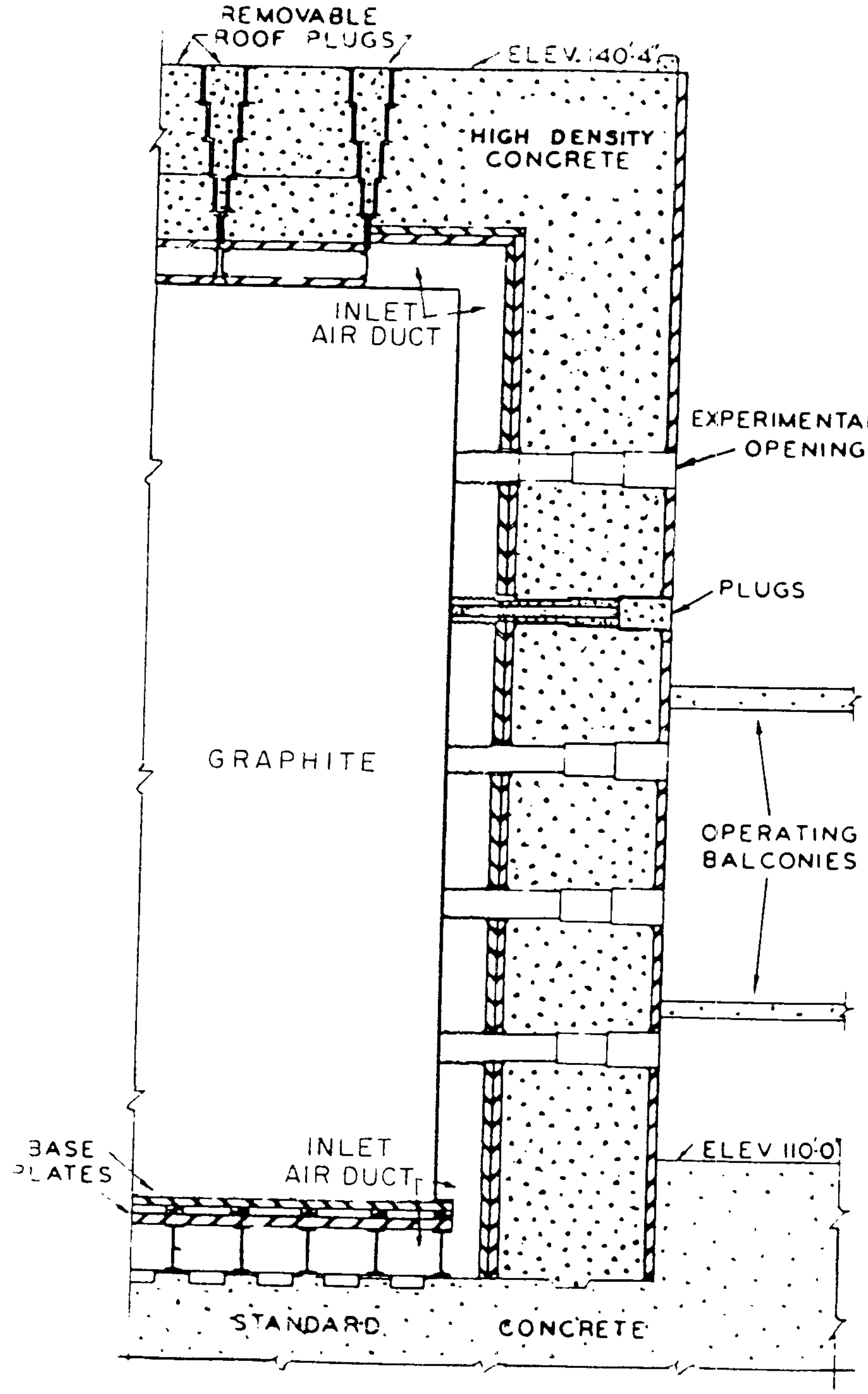

Figure B.14. Section of Biological Shielding

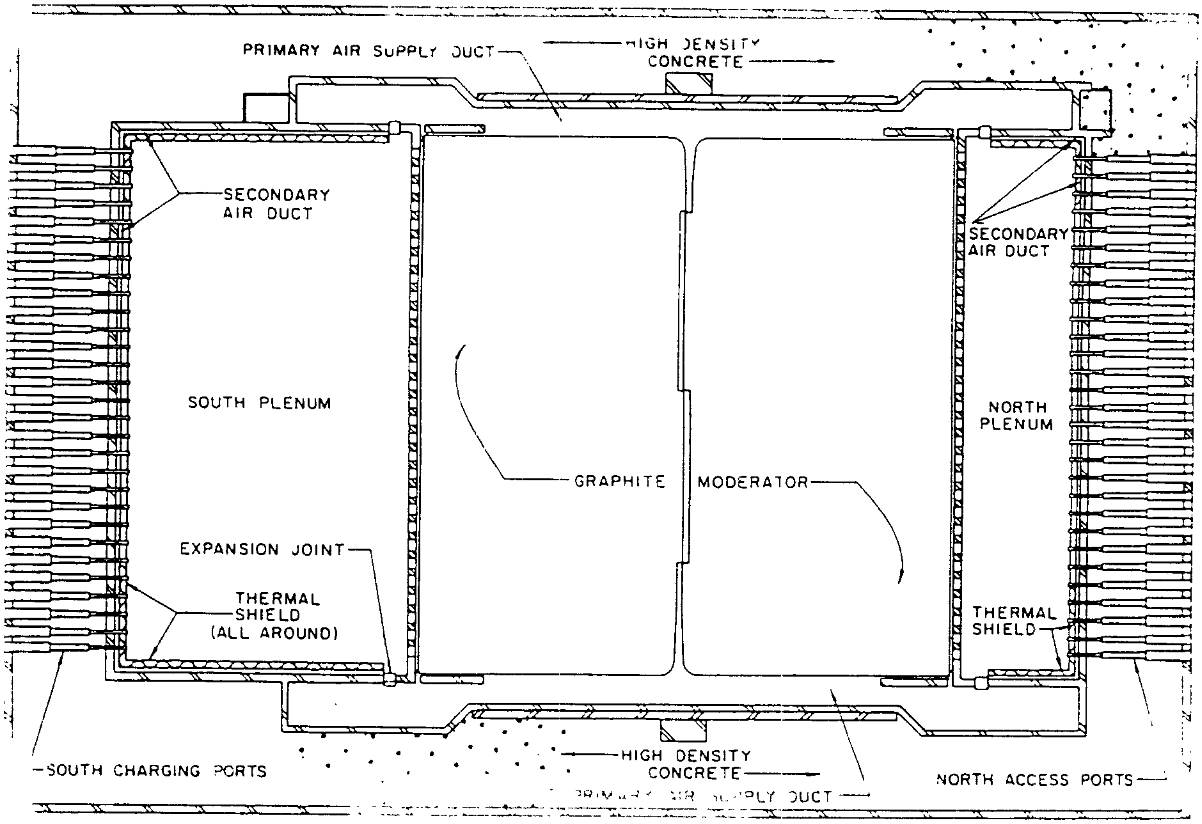

Figure B.15. Plan of Reactor

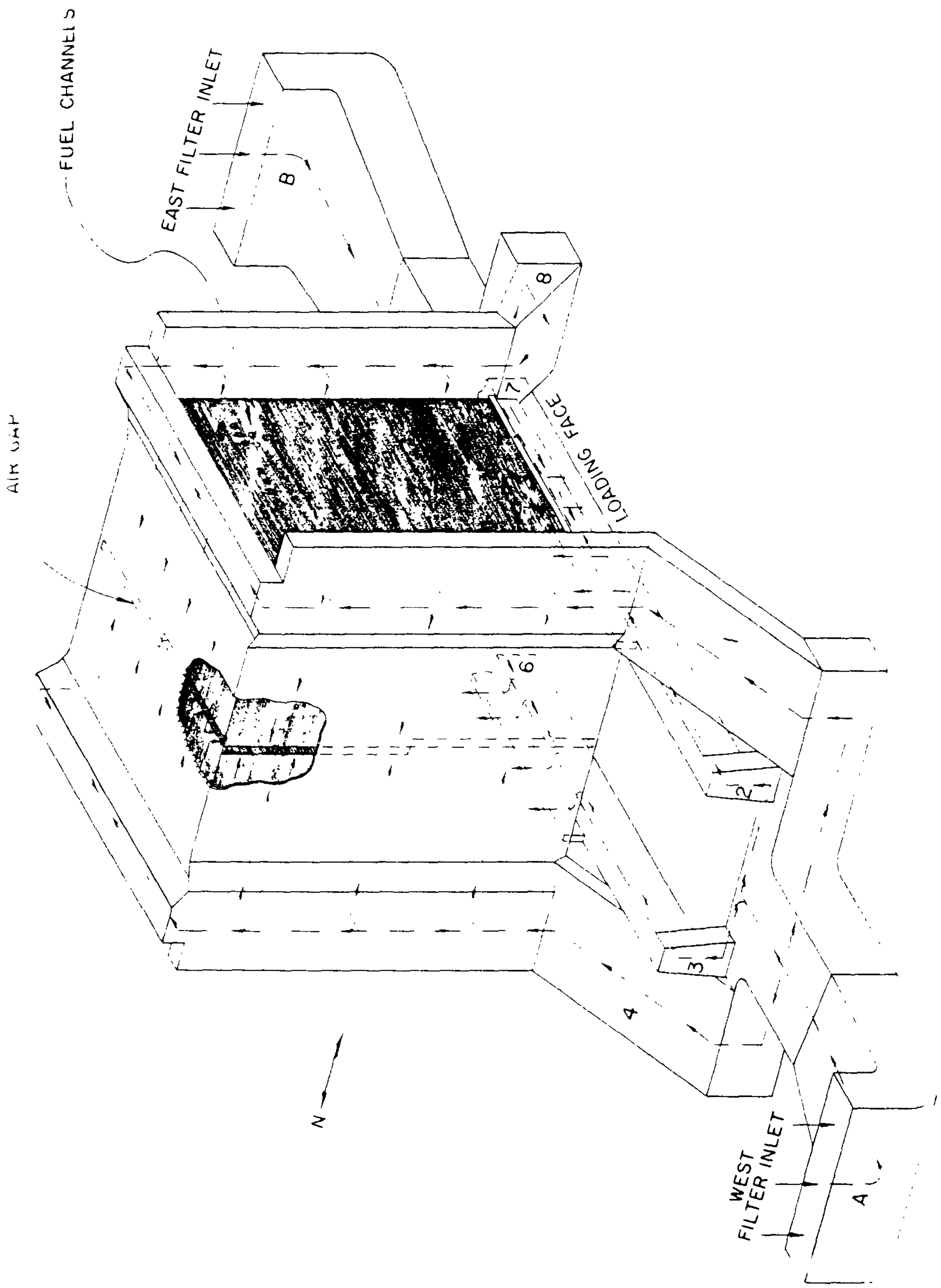

Figure B.16. Inlet Air Duct System

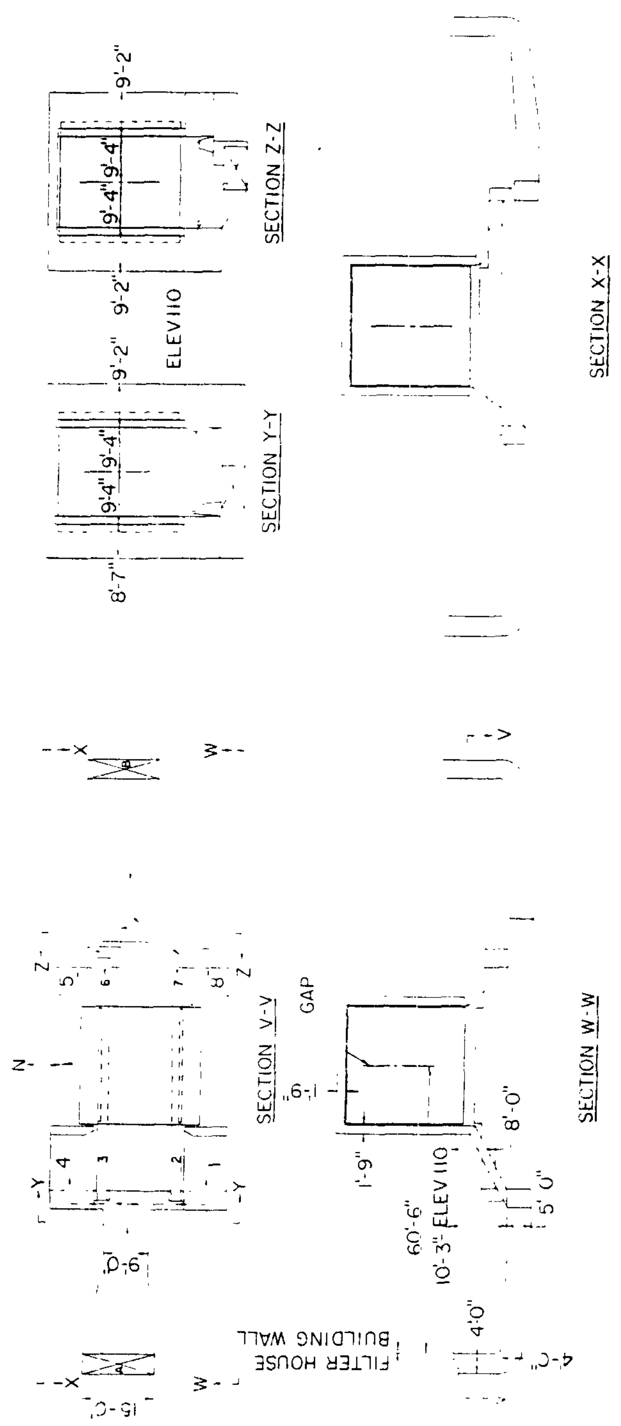

Figure B.17. Sections of Inlet Air Duct System

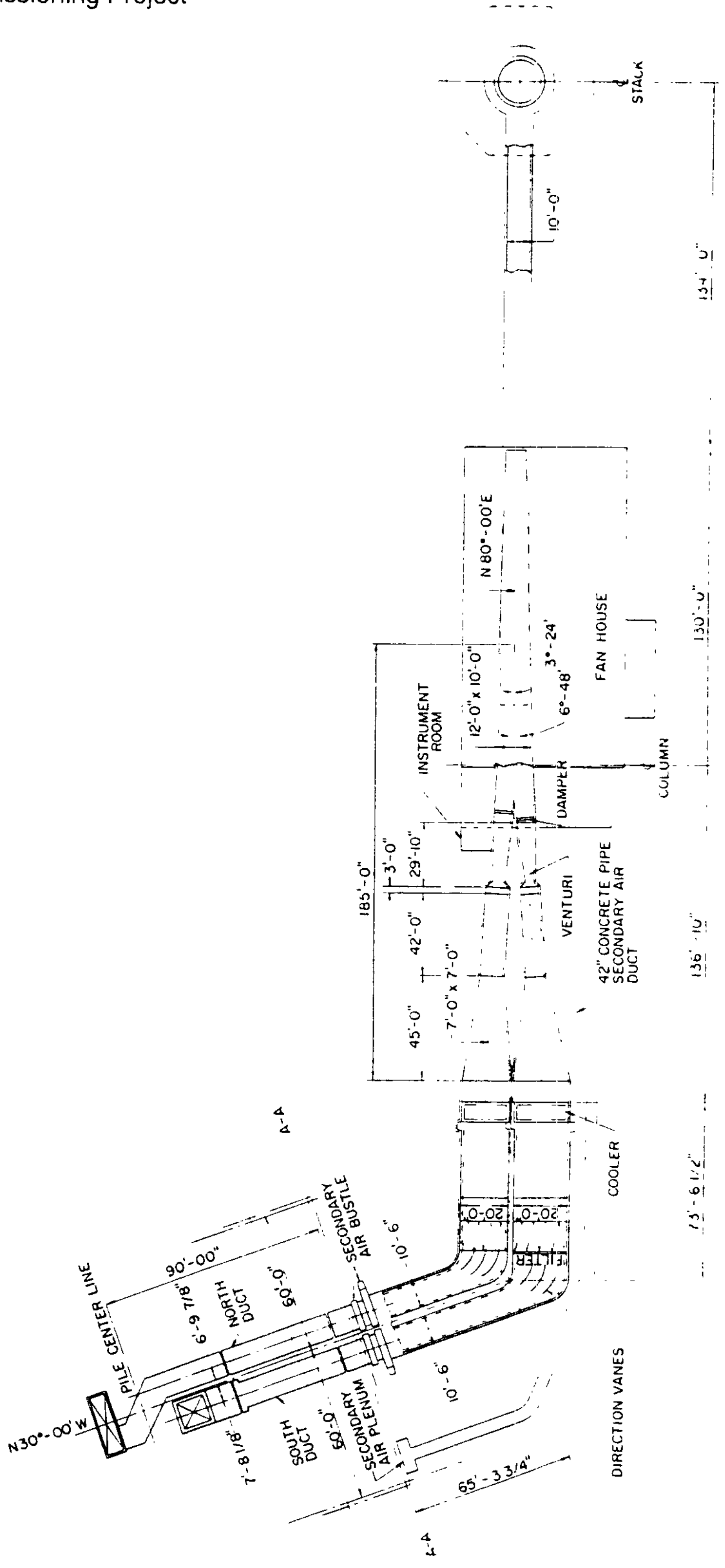

Figure B.18. Plan of Main Air Ducts

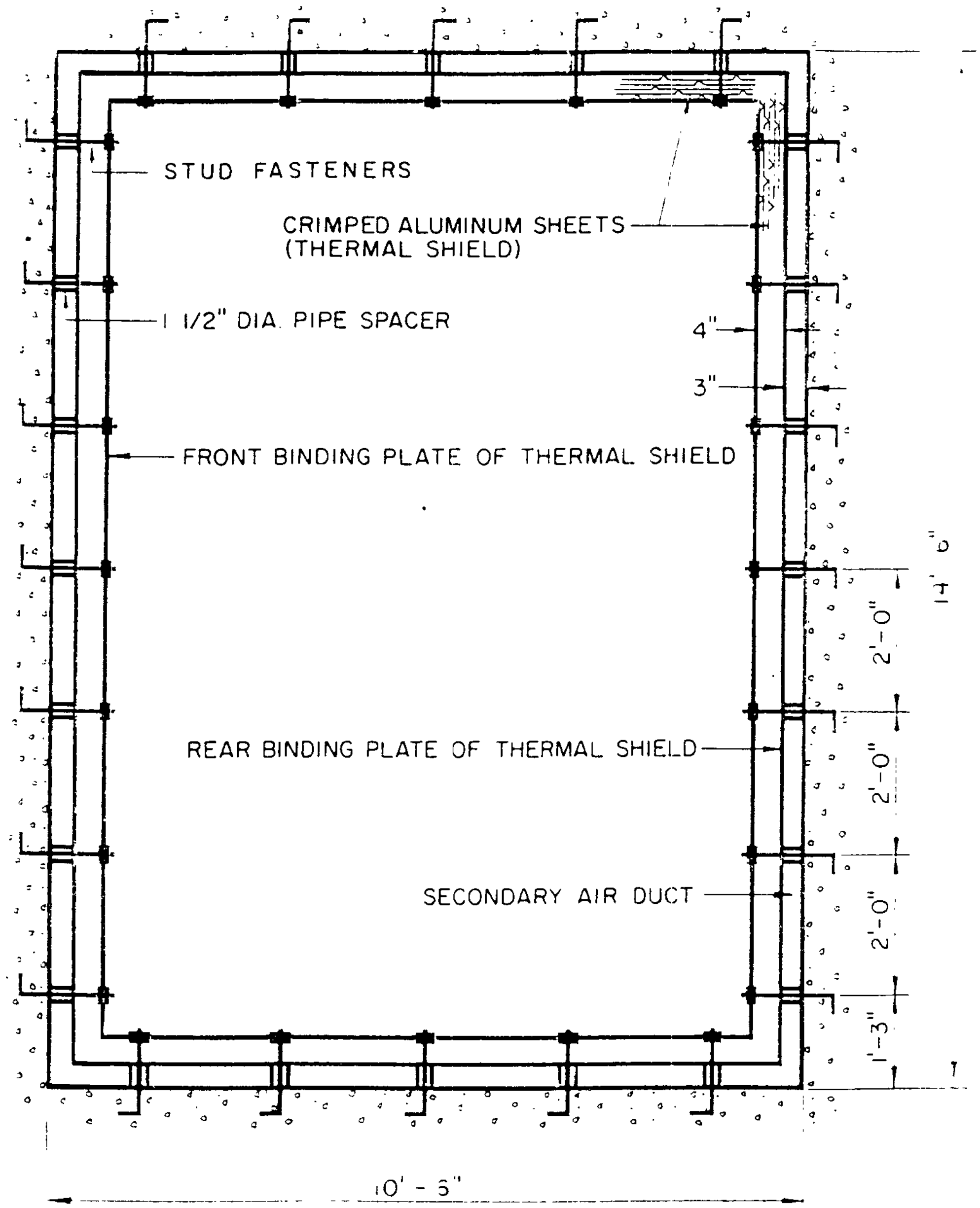

Figure B.19. Secondary Air Cooling System in Exterior Primary Air Exhaust Duct

equipment and controls for the filters and coolers. After passing under Building 708, these concrete air ducts ran above ground, over the roof of Building 704, which enclosed the large primary exhaust fans. The exhaust air then was drawn through these fans and discharged to a stack 320 feet high.

The air-intake ducts have low-point drains that discharge to the subsoil (drywells) near the bottom of the Pile's foundation. The air intakes to the reactor were sealed with plywood covers installed on the curb of the air intakes in the east and west air-intake bays. (To enhance the stabilization and control of combustible inventory, the plywood covers will be replaced with metal, or otherwise fireproofed, within 30 days of approval of this ASA).

The Pile's Negative-Pressure System, consisting of a HEPA filter and fan, draw suction via a hole in the east air-intake cover and discharge directly to the east air-intake bay. (See Section B.3.7 for a fuller description of the Pile's Negative-Pressure System.) The HEPA filter is changed about every five years, or when a pressure drop warrants it, and no radiation above background has been detected on the expended filters. It is unlikely that the low air-flow rate produced by the negative-pressure system could cause the migration of radioactive contamination in the large east intake-duct.

The intake air-filter banks are still installed, though not the original elements. They are fiberglass filters with heavy felt duct seals. There is considerable dust loading on the filters which poses a radiological concern as well as a potential fire hazard. Surveys indicate that the east-intake filter elements originally were contaminated due to work conducted nearby, originating from the canal, during reactor Pile operations.

The exhaust ducts from the reactor were sealed by closing the valves at the discharges of the primary air-fans and the secondary air-fan. The primary air-exhaust duct from the reactor to the coolers is surrounded on all sides by the thermal shield and the secondary air-duct. Due to the construction of the primary duct wall, contamination would likely enter and be deposited within the thermal shield (several crimped aluminum sheets) and on the thermal-shield side of the secondary duct's inner wall. However, the secondary duct's outer wall should be clean, except near any locations where the inner wall of the secondary duct has lost integrity.

The original exhaust-filters are still in place and are expected to be contaminated at >1,000,000 disintegrations per minute. The fin-tube coolers also are in place and have the potential for being contaminated. The cooling-water lines were isolated at the cooling-tower facility, and the piping and coolers were drained. The seals around the filter-vault's manholes and the cooler-vault's plugs are in poor condition, allowing leakage into the ducts. The cooler-vault's plug-lifting points are covered over with cement; the lifting points for the straight- and I-shaped covers on the filter-vault roof are badly corroded.

The air ducts beneath the Pile flooded during operation, and there were sounding devices to detect water in the ducts. On at least one occasion, flooding was caused by cooling water leaking from the coolers. Other potential sources of water are infiltration of precipitation via the filter- or cooler-vault-covers or water from the reactor plenum's wash-down. The configuration of the extension drain pipes suggests that water could drain from the primary ducts into the deep drain sumps. Furthermore, it was apparently necessary to pump the water from the ducts after water was discovered there.

The air coolers were designed for 1,216,000 pounds of air per hour to be cooled from 428°F (220°C) to 120° F (49°C), using water at 85°F (29°C) as the cooling medium. There were two similar sectional tubular-heat-exchangers, one for each exhaust duct. The two coolers were manufactured by the Buffalo Forge Company and were made up of twelve similar Aerofin No. 84 finned-tube units. Each unit contained ninety-six parallel tubes 9-1/2 feet long fastened into removable-type water headers. The units were installed vertically, with the tubes arranged in rows of twenty-four each, four rows deep, with the rows staggered on a 1-7/16-inch triangular pitch. The tubes had 0.049-inch wall, and contained eight helical fins, 0.012-inch thick, per inch of tube length. The tubes and fins were copper, and were bonded with solder which could withstand a maximum air temperature of 550°F (288°C). The tubes were rolled into the tube sheets, which were 5/8-inch copper-plated steel-plate. The tubes and tube sheets were solder-dipped after assembling to seal any voids in them. The headers were cast-iron, machined to fit the tube-sheets and provided with gaskets. The header plates had backoff screws for their removal. The tubes were hydrostatically tested to 2,000 psi before assembly. The units were designed to operate satisfactorily under a working pressure inside the tubes of 150-psi gage with 500°F (260°C) air passing over the outside of the tube bank.

The Instrumentation House, associated with the exhaust duct coolers, and its contents are not expected to be contaminated. It is being used as a storage area. However, the exit air probes were brought into the Instrumentation House to be read, so there is the possibility of contamination.

B.2.5 Deep Pit and Canal Area

During the initial decommissioning work in 1972, the canal was pumped dry, cleaned with soap and water, and shielded with concrete blocks. The concrete slabs still cover the canal and deep pit except at the east-end which is covered with ½" thick aluminum plate (as a full slab of concrete did not fit). There is a hole in one of the west-end slabs which allows inspections and for water to be pumped from the deep-pit. The deep-pit sump is filled in, possibly with concrete and/or sand, with a concrete cap.

The canal walkway flooded and overflowed into the canal and deep pit several times, due to a broken water-line and leakage from the Canal House's roof.

The expansion joints in the canal's walls and floor where it penetrates the reactor building's foundation is a suspect location for leakage. Drawings indicated the presence of a major expansion joint at the reactor building's outer wall. This joint once was believed to be leaking and was covered with fiberglass. Drawings identify other construction joints covered with mastic and/or water-stop seals, including those on each side of the wall at column line 6, on the inside of the wall at column line 7, between the upper deep pit walls and the foundation buttresses, between the canal side walls and floor east of column line 7, and between the canal side walls and floor at the east end wall. (Figure B.20, "Isometric of Canal Area," shows the expansion joint at the building's wall.)

B.2.6 Canal and Water Treatment Houses

The building is a steel frame structure with "Cemesto" (asbestos-based cement) siding. It was cleared of contaminated components and piping. The radiation field ranged up to only 70 mR/hr after a May 1999 cleanup of the hot spots. The higher readings are near the pump pads in the northeast corner and in the equipment cells. The floor drains, which are contaminated, run under the floor to the east-yard sump. The steel shield plates are still in place in cells 3 and 4, and the floor pan is still in cell 4. The floor in cell 4 is below the general floor level, and in the past, water has backed up in this cell from the east-yard sump. The exposed pipe in east end runs underground to Building 801's Hot Lab. The walls of the Water Treatment House are concrete-block. Cell 4 has been verified as dry, and the east-yard sump was pumped dry.

B.2.7 Pile Negative-Pressure System (PNPS) (Figure B.21)

The BGRR Pile was placed in a safe storage mode after defueling, fuel-shipping, and cleanup of the canal water. To support the reuse of the facility as a public museum, the Pile was isolated from Building 701's internal air-space by installing plugs in the biological wall (charging ports at the south face and inspection ports at the north face) and various circular plates on the experimental port openings (east and west faces). On the top of the Pile, all related plugs were reinstalled in their respective openings, two layers of plywood were laid down, and a top layer of carpet placed over the plywood.

The west-intake plenum grading opening was sealed with plywood and the seams were caulked. Plywood was used to seal the east-intake plenum opening, and a HEPA filter and fan were later installed on the top of the plywood. The HEPA was connected with tinwork to an opening in the plywood cover and caulked.

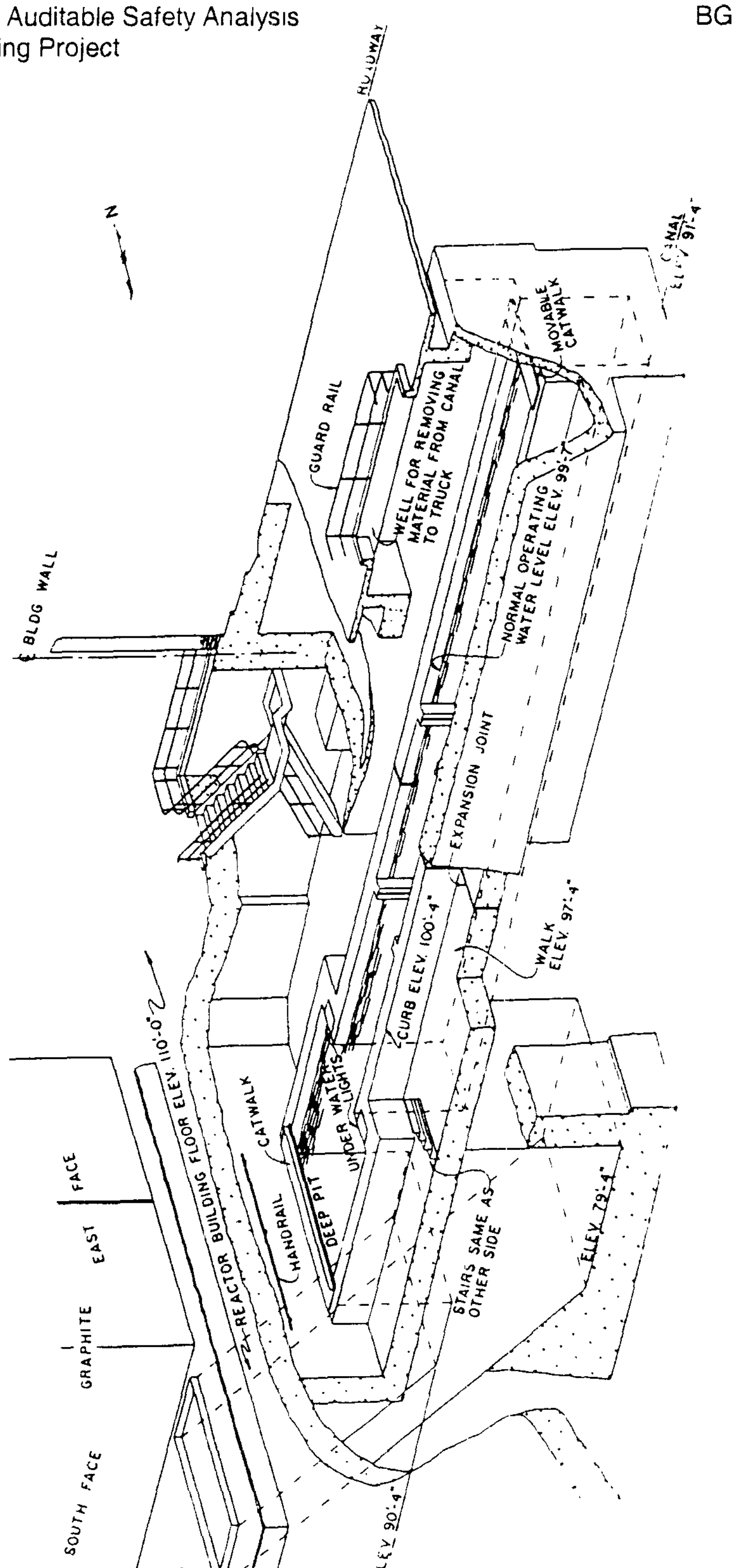

Figure B.20. Isometric of Canal Area

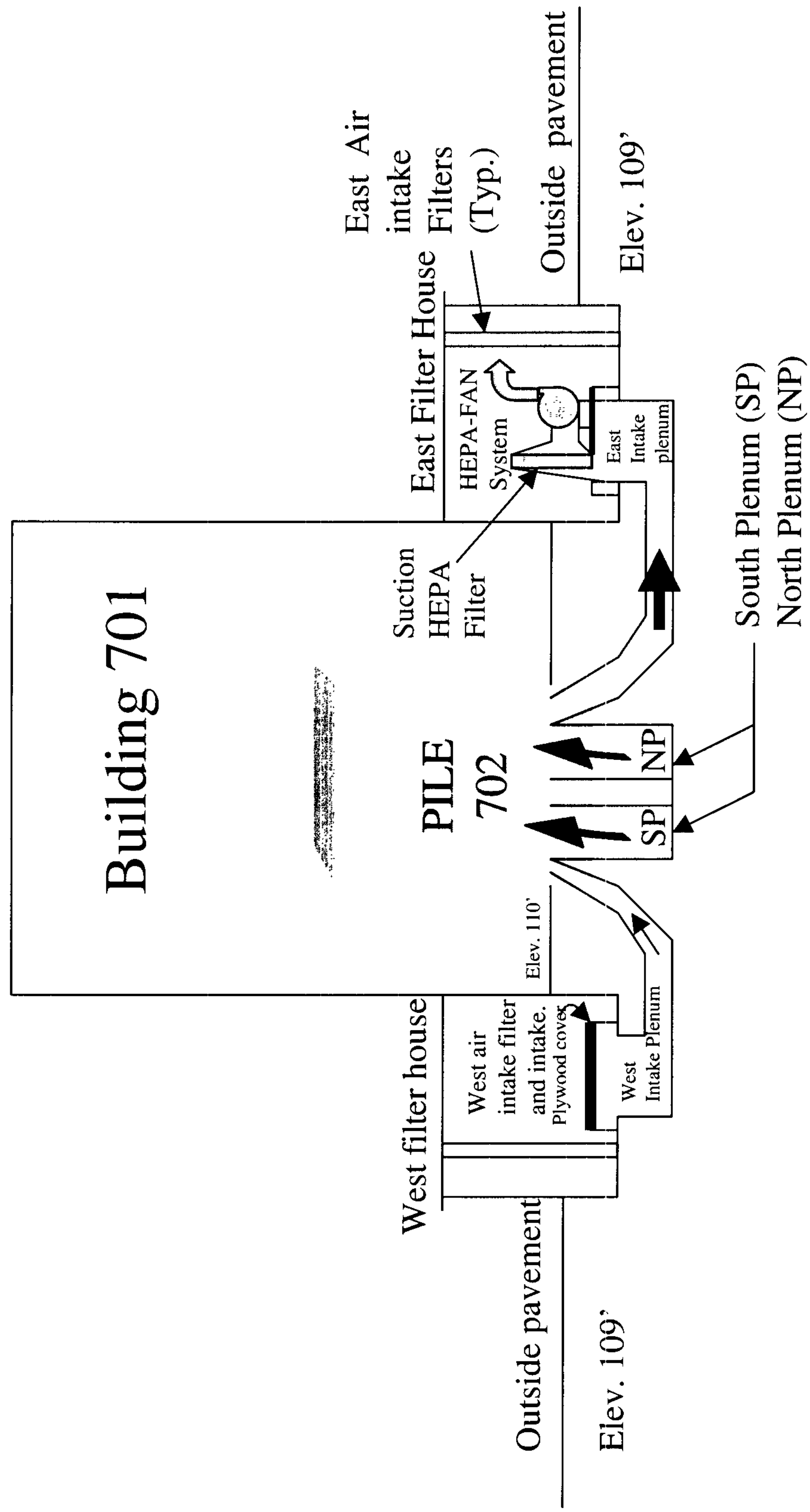

Figure B.21. Pile Negative-Pressure System

The Deep Pit and canal were covered with pre-cast concrete planks and all mating joints were caulked. The overflow sump was filled with concrete, leveled with the canal's north side, and sealed with caulking to the concrete cover. The last east end cover on the top canal is a one-half-inch aluminum plate. The Deep Pit Sump was filled with sand and has a concrete cap. This configuration minimized any leakage into the Pile from the canal area, until the walkway flooded and some water entered the Deep Pit. To pump it out, a small opening was made in a concrete cover on top of the Deep Pit adjacent to the canal through which a suction hose was lowered. This opening is presently covered by concrete, but is not sealed.

The exit-air plenums, South Plenum and North Plenum, and the associated air ducts, are isolated from the fans by closed fan-suction isolation valves. In addition, the secondary air-bypass valve is closed, and the 42" suction-duct line in the secondary plenum vault is sealed with a blind flange.

The spool pieces of the Emergency Fan suction were removed from the duct and blind flanges were installed to seal the Primary duct's openings.

The PNPS fan is drawing the boundary space to a slight negative pressure, approximately -.15 inches water column and 2,800 to 3,000 cfm. The in-leakage is from the following areas: The south-face and north-face plugs are not all sealed or installed; the secondary air-system and the primary exhaust-air have some degraded parts and outside air infiltrates the primary ducts. The drain-cooler sumps are the other source of air infiltration; their covers are rusted and the sump pump-out tubes are degraded. Several instrument taps are rusted and broken off in the Instrument House (Building 708) and the Above Ground Duct.

The fan discharge-air is monitored continuously with a CAM system and any alarms are remotely monitored in Building 600, the Chilled Water Facility. In addition, trends in the fan-filter's parameters are monitored to evaluate the system's performance.

The PNPS system will be removed from service during decommissioning after the Pile is sealed and the passive HEPA is installed.

B.3 Ancillary Systems

B.3.1 Pneumatic Tubes

These six tubes (three sets of two each) rapidly transported samples in specially designed containers from laboratories in Buildings 801, 703 East, and 703 West into and out of the BGRR for irradiation and analysis. The present status of the pneumatic tubes is as follows:

1. All external supplies of pressurized gases were removed. The atmosphere is the same as in Building 702; oxygen levels are not higher.

   - The pneumatic tubes remain in much the same physical condition as when the reactor was operational.
   - The pneumatic tubes are made of aluminum, plastic, and copper.
   - The pneumatic tubes run from the north face of the reactor to the Hot Lab.
   - These tubes run in a trench north of the reactor and leave the reactor building to the east.
   - The tubes were initially contaminated principally by radioactive cadmium, which should have decayed by now. Other long-lived isotopes could still remain.
   - Irradiated samples could be stuck in the pneumatic tubes in areas that are presently inaccessible to survey.
   - The tubes are physically isolated at the entry of Buildings 801 and 703.
   - A radiation survey reports radiation levels between 15 and 40 μrem/hr in the 110-foot elevation on the north face.

B.3.2 Chem-Nuclear Loop

The Chem-Nuclear Loop exists in much the same configuration as when the reactor was operational. It was used to determine the effect of irradiating gases. The only materials studied were pure oxygen and an oxygen-nitrogen mixture. The present status of the Chem-Nuclear Loop is as follows:

- All external supplies of pressurized gases were removed.
- The loop has the same atmosphere as Building 702 (there is no potential for higher oxygen levels).
- The piping from the tanks to the reactor is still intact, and is still installed in the reactor.
- The equipment associated with the tanks was used for "parts" in the past.
- No survey data on contamination are available for this equipment.
- The off-gas vault contains instruments.

B.3.3 East-Yard Pads, Sump, and Storage Vault

During the decommissioning completed in 1984, the three drains in the south pad and the small east pad drain were cleaned, filled with concrete, and tarred over to prevent water leaking into the east-yard sump; the sump was pumped dry and sealed to prevent water intrusion. However, the drain lines from the Water Treatment House were not sealed to prevent any water entering the building from roof leaks then escaping from it at any unmonitored release point (for example, under the door). The sump to which the drains feed is checked biannually.

The three large east- and north-pads drain to the "F" waste line (typically nonradiological and nonhazardous but separate from sanitary wastes) that parallels the east laboratory wing. The pads show numerous cracks, mostly between the east-yard sump and canal house, between the east- and south-pads, between the south-pad and west-door pad, and along the south and west building walls. Contamination under the pads is likely, especially around the east-yard sump.

The storage vault, an approximately 6-foot-diameter vertical cylinder with concrete walls, floor, and 6-inch-thick removable cover, was used to store NU fuel elements with low radioactivity, and also fuel-cask liners and activated and contaminated items. Internal contamination is likely. The storage vault was opened during decommissioning in 1986. It was empty and activity measured a few millirem per hour near the floor. It was subsequently reinspected as part of, or shortly after, a Site-wide Facility Review during Summer 1997; its physical and radiologic conditions have not changed.

B.3.4 Buried Radwaste Lines and Sample Transfer Tubes

The line from the deep-pit sump is a 4" carbon-steel line in 6" split-tile channels. It leaves the canal area above the overflow tank and runs to the contaminated waste-trench. The line was cut and capped at the trench and is capped at the canal.

The line was used in the early days of operation to pump highly radioactive waste water and suspended uranium oxide to the tank farm. Surface contamination remains in the line, but the line itself was verified as drained in summer 1997.

The canal walkway's sump-discharge line was apparently added after the initial construction of the BGRR. This line is routed to Building 801's "D" holding tanks. The canal walkway sumps handled considerable amounts of uranium oxide, as well as contaminated caustics and diatomaceous earth from the water-treatment equipment. Thus, the line is expected to be contaminated with radioactivity. The safety aspects of using these buried radwaste lines was a concern only during the operational phase of the BGRR.

Any radiological contamination or inventory present is part of the BOP estimate of inventory (shown in Section 2.3.2 in the main body of this report).

B.3.5 Building 701 Nuclear-Material Storage Vault

Building 701 Storage Vault was constructed in the early 1950s to hold unirradiated fuel elements for the BGRR. Presently, the vault is used to store depleted- and natural-uranium, thorium, and various radioactive sources in lead containers (or pigs). Special nuclear material (SNM), including enriched uranium fuel and plutonium, is no longer stored in the vault.

The vault is approximately 27-feet wide, 35-feet long, and 23-feet high. The walls are 13-inches thick and constructed of concrete block lined with face brick on the outside. The floor is concrete slab. A small inner vault with a floor space of 60-square-feet is built into the southeast corner of the facility. Its walls are 13-inches thick and the ceiling is 8-feet high and 6-inches thick. The inner vault is kept locked and is used to store precious metals, such as gold and platinum.

No forced ventilation is provided in the vault, and passive ventilation is through two wall grills in the precious-metals vault and when the main door is open. Floor-level scuppers were originally installed in the vault for criticality safety, but have since been sealed. The automatic fire-suppression systems in the vault were deactivated. The storage vault has a rate-of-rise heat detection system in its upper bay and at the ceiling in the lower bay. A fire detected in the storage vault will alarm simultaneously at the facility, at BNL's Fire Department, and at BNL's Police Headquarters. Manual alarm-pull stations for fire (red-pull station) and evacuation (yellow-pull station) are located directly across the loading dock from the vault's security doors [2].

A locked metal cage along the south wall of the main vault includes a floor-level section (the "lower bay") with metal shelves and cabinets containing various radioactive materials including depleted- and natural-uranium foils, pellets, and metal pieces, uranyl nitrates, and thorium metal, and lithium metal. The upper portion of the caged area (the "upper bay") is accessible from a metal stairway in the main bay, and is used mainly to store empty drums and pipe nipples containing depleted-uranium machining chips in oil. Large plates of depleted uranium in wooden packing crates, and several drums of heavy water (D_20) are stored on the main floor of the vault. No fissile material is stored in the vault.

Access to the vault is through combination-lock steel double doors, followed by a sliding fire door. The vault is a secured area with access restricted to only five persons at BNL; all material is accountable and inventoried. Motion detectors tied into BNL's Police Headquarters monitor the facility at all times, and the vault doors are also alarmed into Police Headquarters. The alarm systems are tested each month.

The vault facility has its own Preliminary Hazard Analysis (PHA) [3] and, though originally classified as a nonreactor nuclear facility of Hazard Category 3, through a reduction of inventory by several means, it was reclassified as a "Radiological Facility." It is a segmented and separate facility from the rest of the BGRR, such that the hazardous material in the vault cannot interact with the hazardous material in the Pile nor in the Balance-of-Plant. Furthermore, it is not considered a Confined Space, in accordance with the definition in BNL's Environment, Safety and Health Manual, Procedure 2.2.4, "Confined Spaces," Rev. 4, dated 4/18/95.

B. 4 References

1. Burns and Roe, *Brookhaven National Laboratory BGRR Technical Manual* (Brookhaven National Laboratory, Upton, NY), 1962.

2. Ecology and Environment, *BNL Fire Hazards Analysis, Building 701, Nuclear Material Storage Vault* (Ecology and Environment, Lancaster, NY), August 1993.

3. Ecology and Environment, *Preliminary Hazards Analysis, Building701, Nuclear Material Storage Vault* (Ecology and Environment, Lancaster, NY), August 1993.